HEALTHCARE EXPERIENCES AND OUTCOMES IN OLDER ADULTS WITH HEARING LOSS

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ABSTRACT

Amber Kimball: Healthcare Experiences and Outcomes in Older Adults with Hearing Loss
(Under the direction of Coretta Jenerette)

Background: Hearing loss is the third most common chronic condition in older adults and studies have demonstrated associations among hearing loss and various negative individual health and healthcare outcomes. Little is known about inpatient healthcare experiences with using hearing accommodation for patients with hearing loss and staff who work with them. Little is also known about hearing loss and the association to readmission and length of hospitalization.

Methods: This is a 3 paper dissertation comprising of two separate studies. The first study is a feasibility study investigating hearing accommodation use in an inpatient setting with patient satisfaction (n=25) and nursing satisfaction and perceived productivity (n=15) as outcomes. The second paper is a systematic review investigating hearing loss and the association to hospitalization, readmission and mortality. The third study is a secondary analysis using the National Readmission Database. This two to one (2:1) propensity score matched retrospective cohort study investigated the associations among hearing loss, 30-day readmission, and length of hospital stay. Covariates and primary readmission diagnoses were also examined.

Results: Patients and nurses were generally satisfied with using hearing accommodations during the inpatient stay, and nurses perceived less time spent talking with patients indicating feasibility and acceptability of hearing accommodation use in inpatient settings. In the secondary analysis patients had higher odds of 30-day readmission and slightly shorter hospitalizations compared to their hearing peers. Patient discharge location had the highest effect in both readmission and length of hospitalization models. Patients with hearing loss had higher frequencies of readmissions with primary diagnoses commonly associated with falls compared to hearing peers.

Conclusion: Patients with hearing loss are more likely to experience negative healthcare experiences and health outcomes compared to their hearing peers. Providing accommodations for patients with hearing loss in inpatient settings can benefit both patients and the hospital staff who work with them. Prioritizing and investing in future research and accommodations for patients with hearing loss in various healthcare settings may potentially improve health outcomes, as well as healthcare experiences for hard of hearing patients and the hospital staff who work with them.

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expertise during the early years of my hearing loss diagnosis at the age of 4. I believe that the emphasis on visual, kinetic and auditory access to spoken language by utilizing Cued Speech and the Cochlear Implant simultaneously as well as their knowledge and expertise of critical language juncture is largely why I am where I am today.

I am indebted to my mother, Tammy Wentz-Kimball, who is one of the strongest women I know. Twenty-six years ago Tammy moved halfway across the country for the language intensive Cued Speech preschool program at the mere age of 21 because what was available in Kansas at the time was not considered optimal accommodations for my hearing loss and our family. In Kansas, we lived in a two story country house with a swing in the front yard and a neighborhood full of loving family. In North Carolina, we lived in a basement apartment with little furniture and I had a cardboard box as a playhouse. At the time, family thought she was crazy and couldn't understand why in the world she would move from the comforts of home and a supportive family to a foreign environment where she knew no one. Now, they are so grateful she did, and so am I. Thank you, mom, for always knowing and fighting to do what is best for me. I am forever grateful for you.

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CHAPTER 1: HEARING LOSS IN OLDER ADULTS

Introduction

This chapter will provide a brief overview of the background, purpose, definition, and guiding framework of the proposed research project "Healthcare Experiences and Outcomes in Older Adults with Hearing Loss", description of the proposed 3 paper manuscripts and the significance of this dissertation. I will achieve these goals through; 1) investigating available resources and barriers for hospitalized patients with hearing loss; 2) systematically reviewing studies examining relationships among hearing loss, hospitalization, readmission, and mortality; 3) comparing 30-day readmission rates and length of hospitalization of patients with hearing loss to those without hearing loss, and 4) identifying covariates and primary diagnoses associated with 30-day readmission and length of hospitalization in patients with hearing loss.

Background

"Blindness separates people from things;
deafness separates people from people."

— Helen Keller

Hearing loss is a major public health concern with over 5% of the world population or approximately 360 million people having disabling hearing loss (NCID, 2017). The prevalence of hearing loss gradually increases and worsens as a person ages. For example, nearly 50% of Americans over the age of 70 years have disabling hearing loss, compared to 12.5% of those over 12 years old (NCID, 2017; WHO, 2018). More specifically, one study used the National Health and Nutritional Examination Surveys (NHANES) to show that the overall prevalence of hearing loss was 44.9% for those between ages 60-69, 68.1% for people ages 70-79, and 89.1% for people ages 80 and older (Agrawal et al., 2011). With the growing prevalence of hearing loss in the elderly and the projection that by 2030, over 80 million Americans will be over the age of 65, there is strong indication of a possible growth in need for hearing healthcare research and services (Knickman & Snell, 2002)

Hearing loss is considered to be the third most common chronic condition in elderly Americans and studies have demonstrated negative associations to various aspects of individuals' lives to include physical, emotional, behavioral and social functioning (Arlinger, 2003; Hogan, O'Loughlin, Miller, & Kendig, 2009; McKee, Stransky, & Reichard, 2018; Reuben, Mui, Damesyn, Moore, & Greendale, 1999; Simpson, Simpson, & Dubno, 2015, 2016). Hearing loss and its link to depression and dementia, independent of socioeconomic status, demographics and age, has also been well examined (Arlinger, 2003; Lin & Ferrucci, 2012; Lin et al., 2011). Research has demonstrated the relationships among hearing loss and multiple morbidities including social isolation/loneliness, depression, dementia, falls, cardiac disorders, arthritis, diabetes, and lower self-rated health (Donovan et al., 2016; Gopinath, McMahon, Burlutsky, & Mitchell, 2016; Hsu et al., 2016; Hull & Kerschen, 2010; Lin & Ferrucci, 2012; Lin et al., 2011; Mener, Betz, Genther, Chen, & Lin, 2013; Oh et al., 2014; Stam et al., 2014; Sung, Li, Blake, Betz, & Lin, 2016). Moreover, previous research supports that hearing loss and the ability to perform activities of daily living (ADL) and instrumental activities of daily living (IADL) is closely linked to increased comorbidities (Dalton et al., 2003; Li, Healy, Drane, & Zhang, 2006; Qian & Ren, 2016)

Hearing loss not only has an effect on the individuals' health outcomes, but also on their inpatient and outpatient healthcare experiences. Compared to their hearing peers, those with hearing loss have double the risk of nonadherence, 33% higher healthcare costs, and 10% lower satisfaction regarding quality of provider-patient communications (Cardenas-Valladolid et al., 2010; Mick, Foley, & Lin, 2014; Simpson et al., 2016). Studies have also found that 10% of all hospital readmissions are related to patient non-adherence (Berg, Dischler, Wagner, Raia, & Palmer-Shevlin, 1993; Osterberg & Blaschke, 2005). Previous research has also determined that those with multiple comorbidities and chronic conditions are more likely to be readmitted to the hospital within 30 days and are found to have longer and costlier hospitalizations than those without multiple comorbidities (Donze, Lipsitz, Bates, & Schnipper, 2013; Skinner, Coffey, Jones, Heslin, & Moy, 2016). Previous research also demonstrated that patients with hearing loss whom undergo surgery has been linked to balance dysfunction and increased risk of falls, thus potentially increasing risk of hospitalization and readmission (Lin et al., 2011; Merkow et al., 2015; Yamada, Nishiwaki, Michikawa, & Takebayashi, 2011). These factors can potentially emphasize the importance of ensuring proper communication and patient understanding of their plan of care during hospitalizations (Mick et al., 2014)

Despite the prevalence of, and the well-known negative outcomes associated with hearing loss in older adults, it is often overshadowed by other pressing health conditions in interactions with healthcare providers (Kimball et al., 2017; Li-Korotky, 2012). One potential reason for this oversight is historically, early identification, interventions, and policies for the deaf and hard of hearing has largely been focused on the younger population ("Early identification of hearing impairment in infants and young children," 1993; "Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs," 2007). Though there are limited policies in place for older adults with hearing loss, policy change for hearing loss screening in the younger population has yielded positive results. For example, a policy change with a similar diagnosis (but a different population) took place in the early 1990's with exceptional results. The new policy change regarded newborn hearing screening which is now considered standard practice throughout the US. This was not always the case. When newborn hearing screenings first became a policy requirement in the early 1990's, only high risk babies were screened for hearing loss; this resulted in missing congenital hearing loss diagnoses in certain infants (Green, Gaffney, Devine, & Grosse, 2007). A panel from the National Institutes of Health reviewed the evidence of early identification and interventions of hearing loss, and concluded that it was best practice for all newborns to be screened prior to discharge ("Early identification of hearing impairment in infants and young children," 1993; White, Forsman, Eichwald, & Munoz, 2010). The Joint Committee for Infant Hearing also made suggestions regarding screening by 1 month, diagnostics by 3 months and early interventions by 6 months of age ("Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs," 2007). Early identification and intervention for children with hearing loss has been found to assist with child development of speech and language on par with their hearing peers, thus supporting the importance of appropriate and timely hearing screenings ("Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs," 2007). Due to NIH recognition of the possible implications of hearing loss in newborns, and the implementation of this policy, hearing screenings rose from 3% in 1993, to 98% in 2010 (White et al., 2010).

The policy change for newborn hearing screening yielded positive results, however, currently there are no comparable standards for older adults with hearing loss regarding early identification and intervention. For example, the American Speech-Language Hearing Association recommends hearing screening at least every 10 years, then every 3 years after the age of 50, however, hearing screening in primary care settings typically only occur at 12.9-37% of the time (ASHA, 2019a; McCullagh & Frank, 2013). Cohen and colleagues (2005), reported that 40% of primary care providers stated they did not routinely evaluate their patients for hearing loss and approximately 12% examined for hearing loss at yearly physicals. Wallhagen & Penttengill (2008), found similar results with 85% of patients never being asked or screened for hearing loss during their primary care visits. Furthermore, in (McCullagh & Frank, 2013), providers often documented the assessment of the structure of the ear, but not the function, despite all 30 of their patients having one or more ototoxic medications prescribed to them. In this same study, 93% of providers were unaware of the highly regarded, easy to use screening tool for older adults with hearing loss; Hearing Handicap Inventory for the Elderly Screening tool (HHIE) as well as the shortened version for clinical settings (HHIES) (Ventry & Weinstein, 1983). Often times, providers do not make appropriate referrals, unless patients explicitly complain of hearing loss, and even then referrals may be rare (Danhauer, Celani, & Johnson, 2008; Wallhagen & Pettengill, 2008). For example, in (Wallhagen & Pettengill, 2008), when patients complained of possible hearing deficit, providers often did not take the complaint seriously or providers felt that hearing loss was a natural part of the aging process which should not be made a priority.

Despite the low prevalence of hearing screening by primary care providers, 63% of individuals reported that their primary care provider was the main source of information regarding hearing healthcare (Hase, 2000). Moreover, patients are 8 times more likely to pursue accommodations if their primary care provider makes the recommendation thus indicating the importance of the role primary care providers play in hearing healthcare (Kochkin, 2007). In multiple studies, primary care providers perceived many barriers in the primary care setting when it came to screening their patients for hearing loss during primary care visits. Barriers consisted of provider perceived time constraints, reimbursement issues, and unfamiliarity with; untreated hearing loss implications, available accommodations, and appropriate screening techniques (Cohen, Labadie, & Haynes, 2005; Danhauer et al., 2008; McCullagh & Frank, 2013; Zazove et al., 2017).

The burden not only lies on the providers who see patients to recognize hearing loss, but also on the affected individuals. Hearing loss may not be recognized by individuals as it often occurs symmetrically as well as bilaterally and is slow to progress, subsequently resulting in a delay in seeking hearing healthcare (Arlinger, 2003; Morris, Lutman, Cook, & Turner, 2013). The lack of individual identification, acceptance, knowledge, or ability to advocate regarding their hearing loss could result in disuse of appropriate accommodations. For example, less than 30% of individuals over the age of 70, who would benefit from hearing aids, actually use them (McCormack & Fortnum, 2013). There is strong evidence indicating hearing aides' as a possible quality improvement intervention as it has been associated to improved outcomes such as decreased; depression, length of hospitalizations, inappropriate use of healthcare services and mortality (Fisher et al., 2014; Genther et al., 2015; Mahmoudi, Zazove, Meade, & McKee, 2018).

Though the benefits of utilizing hearing aids are evident, older adults often face many barriers obtaining accommodations. Hearing aids can be cost prohibitive for the elderly as insurance rarely covers them (Donahue, Dubno, & Beck, 2010). Even less costly alternatives such as assistive listening devices may not be covered by health insurance (Mamo, Reed, Nieman, Oh, & Lin, 2016), thus potentially resulting in older adults opting out of making the much needed purchase. There have been few attempts to offset the consequences of hearing loss in older adults on a policy level. For example, there was a recent policy change for over the counter hearing aids; however, there are currently no over the counter hearing aid devices that meet the FDA criteria that can be sold. Therefore, older adults with hearing loss are still required to obtain hearing aids the traditional way (audiology appointment, prescription) (FDA, 2018). As aforementioned, hearing aids are often not covered by insurance for older adults, however, unsurprisingly, insurance coverage for hearing aids mainly cover children. Eighteen states in the US require insurance to cover hearing aids for children (Colorado, Delaware, Georgia, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Missouri, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Tennessee, Texas and Wisconsin) (ASHA, 2019b). This is compared to 5 states requiring insurance coverage for all ages (Arkansas, Connecticut, Illinois, New Hampshire, and Rhode Island). Requirements varied by state for the ages covered, amount of coverage, benefit period, and provider qualifications (ASHA, 2019b). In totality, these states account for less than half of the states in the country. Hearing aids are costly and often cost prohibitive for older adults as hearing aids can range in price from $1,500 to $3,500 from low to high end, respectively. Furthermore, since age related hearing loss often occurs bilaterally and symmetrically, approximately 80% of older adults with hearing loss need 2 of them (Hlayisi & Ramma, 2018). Additional costs for hearing aids are also a normal occurrence with maintenance requirements, occasional appointments to the audiologist, and hearing aid batteries.

In a different attempt to offset the negative consequences of hearing loss, the ADA (American Disabilities Act) was established on July 26, 1990. This civil rights law was to prohibit discrimination of those with disabilities in all aspects of their lives such as; jobs, schools, transportation, public and private settings and buildings (ADA, 2019). In addition to the establishment of the ADA, technology has greatly improved the independence and productivity of those with hearing loss. Technological advances to offset hearing loss such as; hearing aids, cochlear implants and assistive listening devices are available, and have yielded positive outcomes (Cook & Hawkins, 2007; Kochkin, 2007; Mahmoudi et al., 2018; Pichora-Fuller & Singh, 2006). In addition to hearing aids and personal amplifiers, many environmental technological advances were made to assist those with hearing loss and improve independence in their everyday lives. Technology such as TTY, flashing lights for alarms, and visual alerts for sounds such as knocking and phones ringing (ADA, 2019).

With the rapid disappearance and disuse of public payphones and TTY's, the ADA standards are considered to be outdated and has yet to catch up with recent technological advances (Colker, 2015). Moreover, there is a lack of oversight on whether institutions are following the standards of providing appropriate hearing accommodations for those with hearing loss in more private, but pertinent settings (Colker, 2015). These settings include healthcare settings such as the emergency room or primary care offices when access to health information for those with hearing loss is of most importance. As it stands now, there is minimal oversight for hospitals or other healthcare organizations to provide appropriate accommodations for those with hearing loss beyond safety features such as flashing fire alarms, volume control phones, captioned television and qualified American Sign Language interpreters (ADA, 2019; Colker, 2015). Accommodations such as assistive listening devices and real time captions tend to not be priority in these institutions as the majority of the guidelines focus on communication via telephone or interpreters. Though qualified ASL interpreters are necessary, the challenge is that the majority of Americans with hearing loss are over the age of 65 and often do not know ASL

(Boltz, Parke, Shuluk, Capezuti, & Galvin, 2013; Iezzoni, Davis, Soukup, & O'Day, 2003). Lack of accommodations such as real time captioning (talk to text) or assistive listening devices during hospital stays or physician visits can result in loss of autonomy and lack of access to health information for this specific patient population (Boltz et al., 2013). Providing appropriate accommodations for individuals with hearing loss may lead to improved clinical/health outcomes, patient and provider satisfaction, and overall quality of life (Kimball et al., 2017; Piper & Tallman, 2016).

Recognizing and accommodating hearing loss are not the only challenges faced by patients and providers. Challenges are often found within the environments that patients and providers typically communicate. Patients with hearing loss perceive environmental noise as higher and are more vulnerable than their hearing peers to miscommunication and errors when placed in complex, noisy environments (Kramer, Kapteyn, & Houtgast, 2006; Mick et al., 2014). The negative effects of speech processing when patients are exposed to unfamiliar medical concepts and terminology is notably higher in patients with hearing loss (Mick et al., 2014; Wingfield & Peelle, 2015). This disparity may exist because the environment in which the education takes place is often challenging due to medium to high background noise in hospitals (Pope, Gallun, & Kampel, 2013). One study indicated that hospitalized patients with even mild hearing loss may have difficulty understanding and recalling health information (Pope et al., 2013). Patients with mild to no hearing loss recalled 90% of the health information given to them when taught in a quiet environment (Pope et al., 2013). When placed in low, medium and high background noise environments, their ability to hear and recall information steadily decreased. In medium to high noise level environments, which included hospital noise and voices, patients were able to recall approximately 30-42% of the health information provided (Pope et al., 2013).

The combination of patients' difficulty hearing, provider perceived time constraints, and the providers lack of knowledge regarding the available accommodations or consequences of unaddressed hearing loss could result in these patients being less engaged by healthcare providers (Arlinger, 2003). This may motivate providers to take a paternalistic approach when communicating with hard of hearing patients, unintentionally excluding patients from their plan of care. For example, in (Boltz et al., 2013), nurses expressed concern for patient autonomy and control of their own health care, as providers often talk with family members about important medical decisions and may neglect to include the competent patient (Arlinger, 2003; Boltz et al., 2013). Another study investigated the association between hearing loss and patient activation (patient knowledge skill and confidence to participate actively in healthcare) and found that the relationship was statistically significant (Chang, Weinstein, Chodosh, Greene, & Blustein, 2019). Chang et al. also found that the risk varied by hearing severity. For example, patients with little trouble hearing were 1.42 times more likely to have low vs high patient activation. Patients with a lot of difficulty hearing were 1.70 times more likely to have low vs high patient activation compared to their hearing peers (Chang et al., 2019). This indicates that as hearing loss severity worsened there was a higher risk for low vs high patient activation.

Another way providers attempt to reconcile this challenge is by speaking louder in noisy environments to help the patient hear them better. However, louder voices tend to have less clarity and can be more challenging for patients understand (Pope et al., 2013). Ensuring proper communication between patients and providers could result in patients understanding their health information better, subsequently improving health outcomes (Arlinger, 2003).

Definition of Hearing Loss

The World Health Organization (WHO) defines hearing loss as the inability to hear thresholds of 25 dB or better in both ears. Hearing loss can range from mild to severe, and can cause difficulty with hearing conversations and loud sounds. Disabling hearing loss is considered to be hearing loss greater than 40dB in the better hearing ear in adults and a hearing loss greater than 30dB in children (WHO, 2019).

Types of Hearing Loss

Hearing loss is a result of many different causes and can be successfully intervened with medication, assistive devices or surgery, depending on the disease processes (Lasak, Allen, McVay, & Lewis, 2014). There are three different types of hearing loss; conductive, sensorineural and mixed. Conductive hearing loss occurs due to problems in the ear canal, drum or middle ear often requiring surgical intervention. Sensorineural hearing loss, also known as nerve related hearing loss, occurs due to problems in the inner ear, and mixed hearing loss occurs when a combination of conductive and sensorineural hearing loss damages the outer, middle and inner ear (cochlea/nerve) (Lasak et al., 2014).

Age-related hearing loss, also known as presbycusis, and the primary focus of this dissertation is categorized as sensorineural hearing loss. Sensorineural hearing loss is often caused by; exposure to loud noise, head trauma, virus/disease, autoimmune inner ear disease, genetics, aging, malformation of inner ear, otosclerosis, Menieres disease and tumors. Though there are various types of sensorineural hearing losses, causes and available treatments, the most common form is irreversible sensorineural hearing loss. This results in management rather than treatment and is often managed with hearing aids and cochlear implants (Lasak et al., 2014).

Guiding Framework

For this dissertation, the guiding framework is a subset of a revised Donabedian framework (Berwick & Fox, 2016). The Donabedian framework is known for assessing the quality of care through a three-step process; structure of care, process of care, and outcomes. A subset of the revised Donabedian framework will used in paper 1 and paper 3 of this dissertation. In paper 1, *Amplified Hearing Device Use in Acute Care Settings for Patients with Hearing Loss: A Feasibility Study*, the subset of the Donabedians framework was applied with the main focus on the following constructs; individual structure (patients and staff nurses), process of care (effectiveness of using an AHD in two inpatient settings with patients with presbycusis), and individual outcomes (patient and nurse satisfaction and nurse perceived productivity) (Figure 1). In paper 3, *Hearing Loss and the Association with Community Hospital Readmissions in Older Adults: A Secondary Analysis using the National Readmission Database,* the main focus will be on the following constructs; individual structure (patients with hearing loss), and organizational outcomes (length of hospitalization and readmission) (Figure 2). This framework will assist with identifying and understanding the relationships among these variables. As described below, paper 2 is a review of the literature and is not guided by a theoretical framework.

Dissertation Project and Purpose

The overall purpose of this dissertation is to better understand the healthcare experiences of older adults with hearing loss and determine the significant covariates associated with health outcomes in patients with hearing loss in health care settings. Specific goals are to assess feasibility, acceptability and satisfaction of patients and nurses regarding hearing screening and using accommodations in hospital settings. Further, nursing perceived productivity will be measured to give insight as to whether accommodations that may take a few more minutes of their time to obtain, will make a difference in nurses' perception of time spent communicating with their patients. Goals will also include the identification of negative health outcomes that may be associated to hearing loss to include hospitalization, readmission, and mortality, covariates that may affect the relationships and common diagnoses related to readmission for this patient population. Identifying feasibility, safety and acceptability, as well as predictors and consequences of hearing loss will assist with tailoring care and interventions for older adults with hearing loss subsequently improving health outcomes (Piper & Tallman, 2016).

Study Aims and Research Questions (RQ)

Chapter 2. Paper 1. Amplified Hearing Device Use in Acute Care Settings for Patients with Hearing Loss: A Feasibility Study

Aim 1. Evaluate feasibility and safety of utilizing amplified hearing devices for patients with hearing loss in the acute care setting.

Aim 2. Evaluate patient acceptability and satisfaction with utilizing the amplified hearing device in the acute care setting.

Aim 3. Evaluate the acceptability, satisfaction, and perceived productivity of nurses who care for enrolled patients when utilizing amplified hearing devices in the acute care setting.

Chapter 3. Paper 2. Associations among Hearing Loss, Hospitalization, Readmission and Mortality in Older Adults: A Systematic Review

RQ 1. What is the relationship between hearing loss and hospitalization?

RQ 2. What is the relationship between hearing loss and mortality?

RQ 3. What is the relationship found between hearing loss and readmission?

RQ 4. How are older adults screened for hearing loss?

RQ 5. Using the Newcastle-Ottawa scale, what is the quality of each reviewed study?

Chapter 4. Paper 3. Hearing Loss and the Association with Community Hospital Readmission in Older Adults: A Secondary Analysis Using the National Readmission Database

Aim 1: Compare 30-day hospital readmission for patients with and without hearing loss.

Aim 2: Compare length of hospital stay in the index hospitalization for patients with and without hearing loss.

Aim 3: Determine covariates associated with 30-day readmission and longer length of stay in patients with hearing loss.

Aim 4: Investigate most common 30-day readmission diagnoses (DX1) for patients with and without hearing loss.

Descriptions of the Dissertation Manuscripts

The format of this dissertation is three publishable/published manuscripts in lieu of the traditional monograph format. Chapter one of this proposal has provided an overview of the importance of understanding the relationships between hearing loss and healthcare outcomes, the importance of identifying common factors associated to healthcare outcomes and understanding which methods are essential in identifying hearing loss in research. Chapters two through four are described below. Chapter two is a published feasibility study conducted at a level 1 trauma hospital. Chapter three includes is a longer, more detailed version of the published systematic review. Chapter 4 is a pre-publication dissertation version of a secondary analysis using the National Readmission Database. Chapter five is a discussion and conclusion of the results of the three manuscripts and their policy and practice implications and suggestions for future research.

Chapter Two

The title for the manuscript to comprise chapter two is "Amplified Hearing Device Use in Acute Care Settings for Patients with Hearing Loss; A Feasibility Study." The purpose of this manuscript was to evaluate the current available resources as well as the safety and feasibility of utilizing amplified hearing devices in the acute inpatient setting for patients with hearing loss. Secondary outcomes included measuring patient and nursing acceptability and satisfaction, as well as nursing perceived productivity with the device. This manuscript also discusses the challenges and barriers patients with hearing loss face in these specific environments, the limitations of hearing healthcare knowledge in acute care settings, possible correlations of hearing loss to healthcare outcomes in previous research, and the limitations of the available and commonly used accommodations. This manuscript was published in the *Geriatric Nursing* journal in November, 2017.

Chapter Three

The title for the manuscript to comprise chapter three is "Associations among Hearing Loss, Hospitalization, Readmission and Mortality in Older Adults: A Systematic Review." The purpose of this review is to systematically evaluate the current research which investigates the association of hearing loss to hospitalizations, readmissions, and mortality. Evaluation of these studies will assist with conducting future research focusing on hearing healthcare and health outcomes. This manuscript was published in the *Geriatric Nursing* journal in March 2019.

Chapter Four

The title for the chapter four manuscript is "Hearing Loss and the Association with Community Hospital Readmission in Older Adults: A Secondary Analysis Using the National

Readmission Database” The purpose of this manuscript is to present the findings from aims 1-4 in this chapter. A secondary data analysis was conducted utilizing the year 2014 National Readmission Database (NRD) in a retrospective cohort design. The results of this study provide information that might be used to guide future adaptations and tailoring of healthcare to improve health outcomes of this patient population.

Significance to Nursing

Aging occurs in complex ways, therefore, it is time nursing expand current understanding of aging to include health outcomes of individuals with hearing loss. When society develops an understanding of the health outcomes of aging for this group, interventions, health treatments and policy decisions can be tailored appropriately (Piper & Tallman, 2016). By understanding these health outcomes for older adults with hearing loss, efficient and effective resources can be developed to improve access to health information and quality of life for these patients. Further, the public, scientific community, government, and health care community are consistently faced with challenging choices surrounding the use of technology and the subsequent formation of policy designed to care for those with hearing loss. Nursing has been viewed as one discipline that could guide the application of new technology into clinical practice (Huston, 2013), and help guide policy decisions designed to improve the healthcare experience of persons aging with disabilities. However, to achieve this, nursing must begin with an understanding of the health consequences of hearing loss and aging.

It is important to understand the healthcare experiences of older adults with hearing loss and determine the significant predictors of their health outcomes to support the evidence-based practice of health care providers, particularly nurses, as they care for older adults with hearing loss across all settings to include acute, long term, rehabilitation, and community settings. This dissertation is a culmination of studies of older adults with hearing loss to help inform nursing practice and policy regarding the the overall provision of care to older adults with hearing loss.

Chapter Summary

Hearing loss has been found to influence health outcomes, as well as inpatient and outpatient healthcare experiences. Inequities in these outcomes between those with and without hearing loss has also been established. Despite substantial available research regarding inverse relationships, there are gaps in knowledge regarding readmissions. Prioritizing research in relationships among hearing loss, hospitalization, readmission, mortality and hospital experiences; and investigating covariates associated with readmission, will help shape the evidence and policy to guide the provision of care for older adults with hearing loss and over time improve health outcomes.

Figure 1. Paper 1 Revised Subset of Donabedians Framework

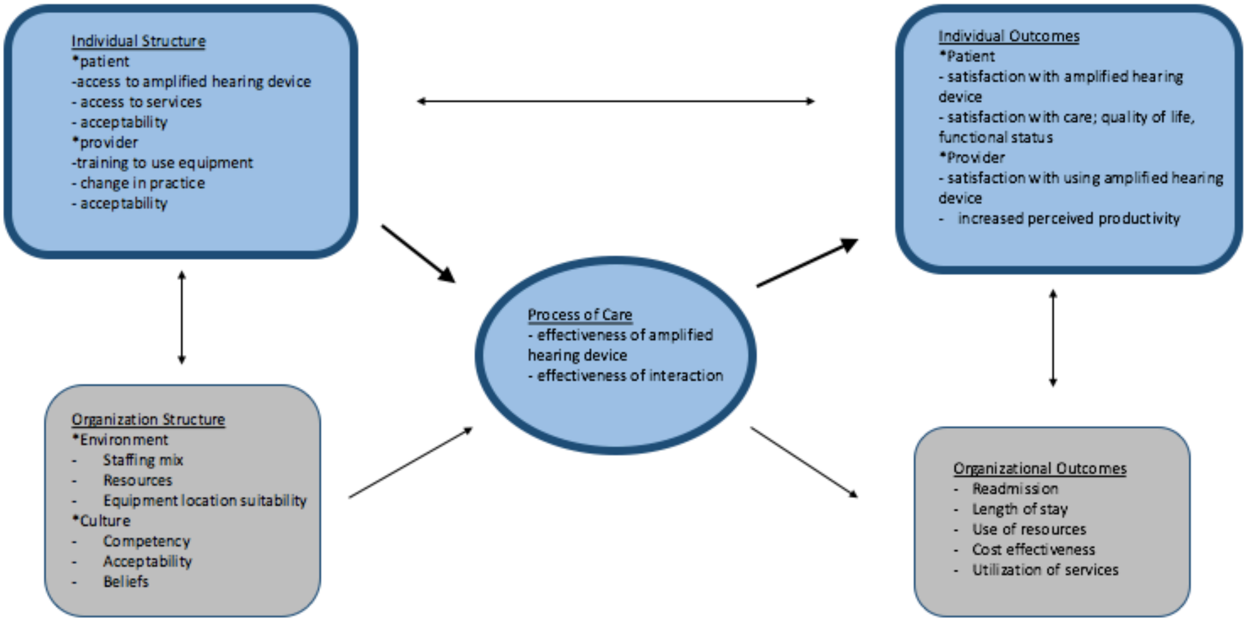
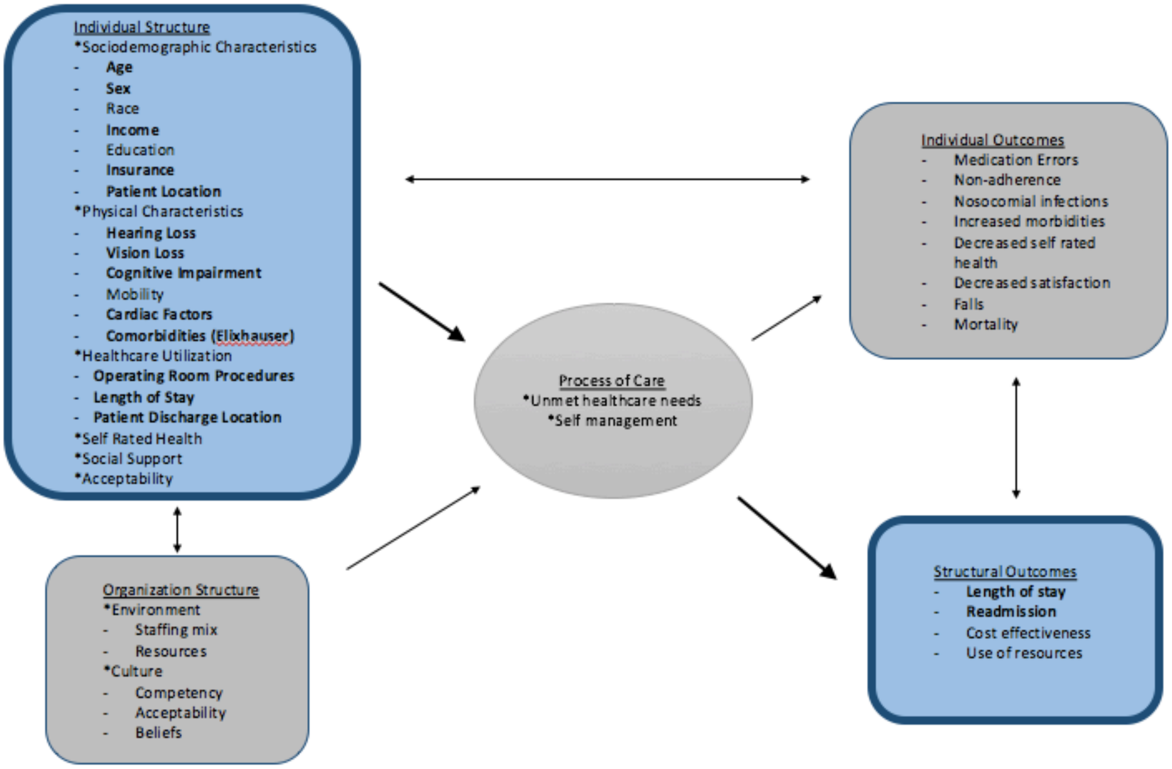


Figure 2. Paper 3 Revised Subset of Donabedians Framework



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CHAPTER 2: AMPLIFIED HEARING DEVICE USE IN ACUTE CARE SETTINGS FOR PATIENTS WITH HEARING LOSS: A FEASIBILITY STUDY [1]

Introduction

Age related hearing loss, also known as presbycusis, is a major public health issue and is the third most common chronic condition in older Americans (NIDCD, 2016). Over 50 percent of people over the age of 75 have presbycusis (NIDCD, 2016), yet it is often underestimated and overshadowed in interactions with healthcare providers by other pressing health conditions (Li-Korotky, 2012). Uncorrected presbycusis has been shown to have negative and disabling effects on individuals' physical, behavioral, cognitive and social functioning (Arlinger, 2003; McKee, 2017). Presbycusis results in reduced speech recognition ability, especially in noisy environments often encountered in many acute care facilities (Kramer, 2006). When compared to their younger peers, older adults with presbycusis recall less information that is verbally provided in environments with high background noise (Murphy, 2000). Furthermore, when in similar noisy environments, those with presbycusis perceive the noise levels and interference with their perception of spoken language as higher than their hearing peers, which can lead to more *cognitive workload* (defined as the effort required to ignore background noise and to

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consolidate important information in short-term memory while discarding what is not important to understand or remember) on the patient (Pichora-Fuller, 2006; Kramer, 2006).

Patients with presbycusis are more vulnerable to miscommunication and errors when placed in complex, noisy environments, especially when they are exposed to unfamiliar words (medical terminology and jargon) that might be encountered in inpatient settings (Mick, 2014). Research has demonstrated that patients with any type of hearing loss have double the risk of medication nonadherence when compared to their hearing peers, and failure to comprehend spoken directions has been found to explain these differences (Cardenas-Valladolid, 2010). Furthermore, studies have shown that when compared to their hearing peers, patients with hearing loss have 33% higher healthcare costs (Simpson, 2016) and more hospitalizations over a 12-month period (Genther, 2015). Although the reason for the increased costs and hospitalizations are unknown, one contributing factor could be that hearing loss can prohibit patients from fully understanding and participating in self-care and healthcare decision-making.

Presbycusis can be a severe obstacle to effective communication between healthcare providers and patients in inpatient settings. The presence of presbycusis is often underappreciated and undiagnosed by healthcare providers (Crews, 2004). For instance, healthcare providers may not realize that the patient is not hearing all that is said to them if the patient indicates through verbal or non-verbal behaviors (nodding their head up and down) that they are understanding or they fail to ask questions. Furthermore, one study found that primary care physicians often did not assess patients for hearing function due to time constraints, reimbursement issues, and provider unfamiliarity with screening techniques (McCullagh, 2012). Without comprehensive knowledge of presbycusis, hearing screening techniques, and the assistive listening devices available, both parties might not recognize that an assistive listening device is necessary to improve communication (McCullagh, 2012). The problem may exist and be unidentified because it is common for adults who suffer from presbycusis to delay seeking help for 10-15 years (Morris, 2013). Adults are often unaware of their own hearing deficits due to the slow progression of hearing loss, and they may fail to seek appropriate accommodations (Arlinger, 2003). Patients who suffer from hearing loss at an older age are also less likely to know about available resources that they are legally entitled to, such as the American Disabilities Act (Iezzoni, 2003). The knowledge deficit extends beyond the individual and also includes healthcare providers' knowledge of the prevalence of this condition and how to accommodate patients who do not have hearing aids (Lin, 2016).

Many healthcare providers do not fully understand the problem of presbycusis and often compensate for the patient's difficulty hearing with interventions that do not solve the problem (Lin, 2016). For instance, lip reading, also known as speech reading, is an intervention that is often utilized in the hospital when patients are unable to hear. However, lip reading takes a lot of practice for the person to master because 70% of spoken words look the same on the lips of another, which increases the likelihood of errors in the patient receiving the correct information (Sommer, 2002). Additionally, barriers such as clinicians not facing patients, talking too quickly or covering their face while they speak, lip color on women and facial hair on men can make lip reading even more challenging (Barnett, 2002). Another common intervention is for the healthcare providers to raise the intensity of their voice. However, louder speech may not be sufficient for a patient with profound hearing loss and could cause further potential damage to the patients hearing (Rabinowitz, 2000). Furthermore, speaking loudly could result in an unintentional violation of a patient's privacy if others in the vicinity might also hear private information.

One study revealed that nurses in the emergency room noticed inappropriate responses of healthcare providers to patients with hearing loss and voiced their concerns about the effects to patients' autonomy and decision-making in health care. These nurses noticed situations where providers adopted a paternalistic approach by talking with family members about important medical decisions instead of the fully competent patient (Arlinger, 2003; Boltz, 2013). Furthermore, patients who suffer from chronic hearing loss may be less likely to be deeply engaged in complex conversations with their healthcare providers due to the increased cognitive workload that is necessary to understand the medical information being relayed to them (Arlinger, 2003). In these situations, the AHD and other accommodations such as caption call or text telephones could benefit both patients and their family members (Stika, 2011). For example, caption call or text telephones could decrease social isolation of hard of hearing patients by improving communication to family and/or friends outside the hospital and subsequently improve the patients' access to their health information (Stika, 2011).

Other accommodations for this specific patient population should be considered to better serve them during their hospital stay. Accommodations such as a computer assisted real time transcription, also known as CART, could be used for hospital wide overhead announcements or for when patients push the call light to request assistance (Stika, 2011). It is often challenging for hard of hearing patients to hear a response through the bedside speaker after pressing a call light, thus making it less efficient and effective for this patient population.

The problem of presbycusis extends beyond safety and quality issues to also affect the satisfaction of patients with providers and their overall healthcare satisfaction. One study found that patients who have hearing loss have a 6% lower satisfaction rate regarding their overall health care experiences compared to peers who are hearing (Mick, 2014). These patients also reported a 10% lower satisfaction rate regarding the quality of doctor-patient communications during the hospitalization (Mick, 2014). Not being able to hear all information while hospitalized can impede their access to critical information regarding their disease processes, necessary treatment regimens, and discharge instructions.

Among adults aged 70 and older with presbycusis who could benefit from hearing aids, fewer than one in three have ever used them (NIDCD, 2016). Hearing aids are rarely covered by insurance programs, including Medicare, and are often cost prohibitive for the elderly (Donahue, 2010). Even less costly alternatives such as amplified hearing devices (AHDs) may not be covered by health insurance (Mamo, 2015). Furthermore, patients who wear hearing aids often come to the hospital without their hearing aids (Smith, 2015). This is often secondary to the urgency of the admission to the hospital, although some patients consciously choose not to bring them due to fears of them getting lost, stolen or broken (Smith, 2015). Without appropriate accommodations for their hearing loss, everyday auditory access to spoken language, including healthcare information, is restricted and represents a barrier to quality healthcare (Crews, 2004).

Purpose

Our study was guided by the following research aims:

Aim 1. Evaluate feasibility and safety of utilizing amplified hearing devices for patients with hearing loss in the acute care setting.

Aim 2. Evaluate patient acceptability and satisfaction with utilizing the amplified hearing device in the acute care setting.

Aim 3. Evaluate the acceptability, satisfaction, and perceived productivity of nurses who care for enrolled patients when utilizing amplified hearing devices in the acute care setting.

Guiding Framework

We hypothesized that providing patients with free access to an AHD while in the inpatient setting would improve patient and nursing satisfaction, as well as improve nursing perceived productivity. To help support this hypothesis, a modified Donabedian framework was applied to our feasibility study (Berwick, 2016). The Donabedian framework is known for assessing the quality of care through a three-step process. The three steps are structure of care, the process of care, and outcomes. The modified Donabedian framework was applied with the main focus on the following constructs; individual structure (patients and staff nurses), process of care (effectiveness of using an AHD in two inpatient settings with patients with presbycusis) and individual outcomes (patient and nurse satisfaction and nurse perceived productivity). The structure of care as defined and applied in our feasibility study are the patients and staff nurses who participated and their attributes such as access, acceptability, and training. The process of care as applied is the effectiveness of using the amplified hearing devices in the inpatient setting for persons with presbycusis. The outcomes measured were satisfaction for both patients and nurses and nurses perceived productivity.

AHDs are an inexpensive intervention that can lead to patients' improved understanding of their interactions with healthcare providers, which may lead to improved patient satisfaction and decreased morbidity. Healthcare providers may also benefit from patient utilization of AHDs, as it may take less time to communicate with patients who are able to hear. Use of AHDs may potentially translate to hospital cost savings, as one study found that utilization of hearing aids was significantly associated with shorter hospitalizations (Genther, 2015). Even patients who utilize hearing aids may benefit from the AHD on a short-term basis. An AHD provided by the hospital could be an inexpensive stopgap until the patient's hearing aid is brought to the hospital or until the patient is discharged.

Methods

This feasibility study is a first step in learning how AHDs can be used in the acute care setting. A combination of qualitative and quantitative methods were used to evaluate whether we could easily recruit research participants (both patients and their nurses) who would both understand and follow-through on the research protocol as written (find it acceptable and not a burden to care), whether patients with presbycusis who could benefit from an AHD could be easily identified by nurses through either self-report or use of the HHIE-S, and whether patients and nurses would evaluate the AHD as a suitable device as an intervention for this problem.

Setting and Sample

After approval from the Institutional Review Board at the hospital the study was conducted, written informed consent was obtained from hard of hearing patients who met the study criteria and nurses who cared for any of these patients. Data were collected on two inpatient neurosurgery and acute care for the elderly (ACE) units at a hospital in the southeastern United States from November 2015 to January 2017.

Patient inclusion criteria included at least 18 years of age and a perceived hearing handicap supported by a score of at least 10 on the Hearing Handicap for the Elderly Screening Version (HHIE-S) instrument (described below). Patients were excluded if they were unable to use the AHD without assistance after a brief training period, had a cochlear implant, used a hearing aid during their inpatient stay, were non-English speaking, were restrained chemically or physically, or were not oriented to person, place, time and situation.

Study Measures

Hearing Handicap for the Elderly Screening Version (HHIE-S)

The Hearing Handicap for the Elderly Screening Version (HHIE-S) instrument was used to screen patients' perception of hearing handicap. The HHIE-S is an easy to administer, 10 item questionnaire with an internal consistency reliability score of 0.87, making it an efficient screening tool to utilize in a hospital with high traffic and turnover for both patients and staff (Demers, 2013). The HHIE-S consists of 5 emotional questions and 5 social questions with scores ranging from 0 to 40 points. Zero points indicates no reports of perceived social or emotional detriments from the individual's hearing loss, and a score of 40 implied high perceived social and emotional detriments from his or her hearing loss. Patients rank their perspectives on their hearing handicap by a Likert scale from 0-4 (0 = no, 2 = sometimes, and 4 = yes). Patients who scored 10-24 points were likely to have mild to moderate perceived hearing handicap, and patients who scored 24 – 40 points were likely to have significant perceived hearing handicap.

Post-Intervention Satisfaction Surveys

The patient and nurse surveys, developed by the interdisciplinary study team, which included a physician, a nurse, and an individual with hearing loss, consisted of both closed and open-ended questions. The patient survey aimed to evaluate participant's satisfaction with the AHD and interest in using it again in future hospitalizations The nurse survey aimed to assess the nurses' satisfaction with the AHD and their appraisal of its effect on their productivity when interacting with a patient using the device. (See Table 1 & 2).

Intervention: Amplification Device

The Reizon Loud Ear Personal Amplifier (Palmer, 2017) was selected due to its small size, low cost ($29.95 each), and ease of cleaning with hospital grade disinfectants. It was also selected for its ability to be clipped on the patient's gown for convenience. The AHD was cleaned after each participant's discharge using standard hospital procedures for cleaning patient devices, and earbuds were replaced for each participant.

Procedures

The study team held three training meetings to educate day and night shift nurses on both units regarding use of the AHD with study patients. Patient recruitment began at the staff nurses' initial assessment of patients for possible hearing loss. Patients who reported hearing loss or were suspected to have hearing loss were identified by nurses and referred to the study team. A study team member approached the patient and informed the patient about the study. If the patient expressed interest, the patient was then screened with the HHIE-S and eligible to enroll if they had a score of at least 10. Inclusion and exclusion criteria were applied and those patients who were eligible were given the opportunity to ask questions about the study and provide written informed consent. Consented patients were then trained on how to use the AHD

Data Analysis

Analysis of numerical data, demographics, patient outcomes and nurse outcomes, were performed using SAS version 9.3. Qualitative data were reviewed by study team members to understand context and compare responses across subjects and settings.

Results

A convenience sample of 25 patients and 15 staff nurses on two inpatient units participated in the study. Approximately 31 patients were approached about participating in the study. Reasons for denial/exclusion from the study included current hearing aid use (n=2), early discharge (n=2), feeling too ill (n=1), or disinterest (n=1). All nurses who cared for the patients consented and completed the AHD survey.

Patient Demographics

Patients were enrolled from the neurosurgery (*n* = 12) and the ACE (*n* = 13) units. Patients' ages ranged from 68 to 95 years of age (mean = 83.6; STD = 7.5)). Enrolled patients included 10 females and 15 males. Sixteen patients reported using a hearing aid at least some of the time, with 10 of the 16 using a hearing aid regularly. A total of 17 subjects had impaired hearing for 10 or more years. On average, participants used the AHD for 2.4 days during their inpatient stay.

Patients scored an average of 29.5 out of a possible score of 40 on the HHIE-S instrument (STD = 5.6), with a range of 22 – 40 points (See Table 3). Males and females scored comparably (male mean: 29.5, STD = 5.7), (female mean=29.6, STD = 5.7), and scores were also similar by hospital unit (neurosurgery unit mean=29.3 (STD = 5.2), (ACE unit mean = 29.7, STD = 6.2).

Patient Outcomes

Twenty-four out of 25 patients reported that the device helped them to hear the conversations directed towards them by healthcare providers, and these same patients expressed interest in reusing this device in future hospitalizations. In fact, two patients reported purchasing an AHD for home use before being discharged from the hospital. One patient expressed dissatisfaction with the AHD and indicated that they would not use it again in future hospitalizations. This patient reported wearing hearing aids prior to enrollment in the study and scored a 40 on the HHIE-S.

Nurse Outcome

All 15 nurses reported the AHD was beneficial and would recommend it to future patients. Nurses reported that the time spent communicating with patients using the AHD was reduced. On a scale from 1 to 10 representing the nurse's overall satisfaction with the device, with 10 being the most satisfied and a score of 0 not satisfied at all, 14 of 15 nurses reported a score of 8 or greater (*n* = 1 reporting a score of 8; *n* = 2 reporting a score of 9; and *n* = 11 reporting a 10). One nurse did not report a number and only stated "yes". Additionally, all nurses reported that patient utilization of the AHD resulted in some time savings. There were no reported complications from patients or the participating nurses associated with use of the AHD.

Discussion

Our findings suggest that patients with hearing loss and nurses who cared for them were generally very satisfied with using the AHD in the inpatient setting. Our data also demonstrates that the AHD was safe to use and easy to implement in an appropriate patient population. In our experience, training a patient and nurse to use an AHD takes less than five minutes. Investing such a small amount of time at the beginning of a patient's inpatient stay may lead to overall time savings for both the patient and healthcare staff.

Throughout this study, the high turnover of patients made it difficult to obtain patients that could use the device for more than one day. Additionally, several hard of hearing patients on both units had some degree of cognitive impairment which excluded them from this study. Hearing loss has been found to have a strong correlation to cognitive function decline according to many studies (Arlinger, 2003; Li-Korotky, 2015; Gurgel, 2014). Further research is needed to assess the feasibility and effectiveness of utilizing AHD for patients with hearing loss and cognitive dysfunction in acute care settings as it would require a unique design to test patient outcomes.

A prevalent concern among patients was cost of using the AHD during their hospital stay. Consistent reassurance was needed to ensure that patients understood that the AHD was free to use. High nursing staff turnover during the study recruitment period made it difficult for all nurses to be aware of the study. Therefore, it is recommended to have at least one consistent study team member or a committed staff member on each unit to assist with patient recruitment.

It is important to acknowledge that AHDs are only appropriate for a specific cohort of patients with hearing loss. For example, patients with cochlear implants cannot utilize this AHD. Patients in an ICU setting may have difficulty using an AHD, as the degree of background noise secondary to telemetry monitors, oxygen equipment, and other devices may lead to a degree of background noise incompatible with comfortable use of an AHD. Because an AHD requires a patient to be able to self-regulate the device's decibel level and to turn it on and off, only patients who are completely alert and oriented will be able to utilize the device safely.

Audiometric testing is considered to be the gold standard for evaluating hearing loss (Valete-Rosalino, 2005). However, it would be unrealistic for audiometric testing to be used as a screening tool in the acute care setting, as such testing is typically time consuming and performed by a trained audiologist. Therefore, it is important to identify a screening tool that can be easily administered by any healthcare professional when a patient is admitted to the inpatient setting. Because the goal of the study was to evaluate the feasibility of implementing AHDs in an acute care setting, we recognized that it would be unrealistic to utilize an audiologist to conduct this type of testing. Although the HHIE-S is subjective and has its limitations, it is easy to explain, easy to apply, and effective at assessing the perception of hearing loss in patients' everyday life (Demers, 2013). We recognize that there are limitations to utilizing the HHIE-S, as it can only be effectively used in patients whom are cognitively intact and can respond in verbal or in written form (Demers, 2013). Also, self-reported measures are subjective and rely heavily on patients' knowledge, candor and acceptance of his or her hearing status. One study indicated that hearing loss is often underestimated and underreported by older adults. As a consequence, their self-reported screening results did not match with their objective or audiometric testing (Ramkissoon, 2011).

Providing accommodations for patients with hearing loss may not only lead to increased patient satisfaction, but also improved clinical outcomes (Piper, 2016). Patients with hearing loss are more likely to suffer from additional stress and fatigue in an inpatient setting due to the higher degrees of concentration required to understand verbal communication when compared to their hearing peers (Arlinger, 2003). Stress and fatigue are shown to delay physical and emotional healing to other conditions and have a negative effect on patient cognition and health outcomes and may lead to further disparities in health outcomes for this population (Juster, 2010). This could result in prolonged hospital stays, decreased satisfaction with care, and increased lengths of their hospitalizations or readmissions after discharge. Key public institutions and groups have recognized this problem as a public health crisis and listed hearing loss in the top 25% of priority public health topics to address in future research (Wall, 2000). Importantly, the assumption that the best care for persons with hearing loss is synonymous with the most advanced technology provided by hearing aids, which are costly and typically not covered by third party payers, has been questioned (Donahue, 2010; Genther, 2015; Lin, 2016).

Limitations

While this study demonstrates some important preliminary findings critical to moving research forward in this area, we also want to recognize the limitations of this study. Because the study was designed to be a feasibility study, the study sample size was small and underpowered for more complex statistical analysis to evaluate causal processes on patient discharge outcomes (e.g., patients' understanding of their discharge information, decreasing hospital readmissions after discharge, improved patient engagement in self-care after discharge) (Tickle-Degnen, 2013). The findings from this study should not be generalized, as we recruited a small number of patients from two hospital units within one large teaching hospital in the Southeast of the United States. Further studies designed to evaluate the efficacy of AHDs will need to include a larger sample size and better ascertained outcomes to answer these questions. Additionally, the instruments used to evaluate patient and nursing appraisals were specifically designed for this study and did not undergo any testing for external validity. The outcome measures were subjective, and future studies designed to evaluate efficacy will need to include objective measures to precisely measure the amount of nursing time saved and to evaluate long-term outcomes focused on issues such as patient understanding and compliance with discharge instructions, prevention of patient readmissions, and how use of the AHD might affect patient engagement in self-care during their hospitalization, in the discharge process, and after discharge.

Lessons Learned

Several lessons were learned in the process of this feasibility study. First, a small number of patients and nurses were recruited from two inpatient floors only. Both floors are considered medical-surgical (med-surg) level meaning patients were usually stable. Hearing accommodations such as assistive listening devices or amplified hearing devices may not be optimal in other acute care settings such as the emergency department (ED) or even intensive care unit (ICU) settings. Emergency department settings are often chaotic with a primary focus of stabilizing patients and transporting them to appropriate destinations whether its inpatient (ICU, med-surg) or outpatient (home, long term care facilities). Though ICU settings are often less chaotic than ED settings with different goals for patient care, ICU settings still may not be an optimal setting to implement hearing accommodations as often times patients are often very sick therefore potentially unable to use hearing accommodations independently. More research regarding the feasibility of using these devices in other types of settings including these two settings with larger sample sizes is needed to better understand the implications for both patients and nurses.

Another consideration is that equipment such as oxygen humidifiers and telemetry monitors may interfere with the benefits of using hearing accommodations. For example, amplified hearing devices amplify all sounds, (unless it has beam forming capabilities), not just speech, which can sometimes actually worsen communications between patients and hospital staff. Due to the high likelihood of background noise in acute care settings interfering with the benefits of hearing accommodations such as amplified hearing devices, considerations of using amplified hearing devices that have beam forming capabilities should be considered for future research. Research comparing different kinds of hearing accommodations in various healthcare settings would also be beneficial to see if certain types of hearing accommodations are optimal for certain healthcare settings.

Though satisfaction of patients is an important outcome as it has been associated to health outcomes in previous research, more research needs to be done to assess whether hearing accommodations assisted with patients obtaining and consolidating health information prospectively. For example, future research could consider using a teach back method to assess if utilization of the hearing device led to improvement in patients receiving health information. Future studies can also factor in other health outcomes prospectively such as 30 day readmissions, types of questions patients ask at follow up appointments, understanding of disease processes and adherence to medication regimens. It is also unknown how many patients whom own hearing aids actually bring them to the hospital during their inpatient stay. Future research can investigate the number of patients who own hearing aids and how many actually bring them to the hospital and the reasons for their choice. Our study found that over half of study patients wore hearing aids; however, they did not bring their hearing aids to the hospital. This suggests that though patients may own their own hearing accommodations, there may be reasons as to why they do not bring them to the hospital.

Conclusion

Feasibility studies can be cost effective modalities to gain insight into important clinical questions (Taylor, 2007). Our study has provided important preliminary evidence to suggest that many hard of hearing patients are willing to participate and may benefit from inexpensive AHDs during their inpatient stay. Our study has demonstrated that AHDs are safe and easy to implement in an acute care, inpatient setting. Both patients and nurses were overwhelming satisfied with using the AHDs in these settings. This feasibility study could be used as a basis for larger prospective studies aimed at determining whether AHDs can increase patient satisfaction, compliance, support patient health information consolidation, and improve population health outcomes in the acute care setting and in other social environments. This study provides preliminary evidence to encourage further studies in this area.

Table 1. Post-Amplified Device Use Survey

• How long have you had difficulty hearing?
• Do you wear hearing aids? If so, do you wear them regularly?
• Have you been consulted by an audiologist? If so, what were the results?
• Do you have difficulty hearing conversations on a consistent basis?
• Do you have difficulty hearing healthcare professionals (i.e. MD, RN, Therapy etc)?
• Do you feel that the amplified device helped you hear well during your hospital stay?
• Would you want to use this device if you were hospitalized again?

Table 2. Amplified Device Use Nurse Survey

• Were you satisfied with the amplified device? Rate your satisfaction with the amplified device from 1-10. 1 for not satisfied and 10 for very satisfied.
• Do you feel like utilizing the amplified device benefited the patient? How so?
• Do you feel like utilizing the amplified device benefited health care professionals communicating with the patient? How so?
• Was the time spent in the patient's room shortened due to the amplified device? If you can calculate as a percentage, how much time was shortened?
• Would you recommend this amplified device to patients with hearing loss? If no, why not?

Table 3. Patient HHIE-S Scores – Emotional (E) & Social (S)

	Gender				All	
	F		M			
	N	Percent	N	Percent	N	Percent
E-Cause arguments						
No	4	40%	5	33%	9	36%
Sometimes	4	40%	6	40%	10	40%
Yes	2	20%	4	26%	6	24%
E-Embarrassed to meet new people						
No	1	10%	2	13%	3	12%
Sometimes	2	20%	4	26%	6	24%
Yes	7	70%	9	60%	16	64%
E-Feel handicapped						
No	2	20%	2	13%	4	16%
Sometimes	5	50%	7	46%	12	48%
Yes	3	30%	6	40%	9	36%
E-Cause frustration with family						
No	1	10%	1	6%	2	8%
Sometimes	1	10%	2	13%	3	12%
Yes	8	80%	12	80%	20	80%
E-Hamper life						
No	2	20%	2	13%	4	16%
Sometimes	2	20%	5	33%	7	28%
Yes	6	60%	8	53%	14	56%
S-Attend church less						
No	4	40%	7	46%	11	44%
Sometimes	2	20%	5	33%	7	28%
Yes	4	40%	3	20%	7	28%
S-Difficulty hearing TV/Radio						

No	0	0%	1	6%	1	4%
Sometimes	2	20%	3	20%	5	20%
Yes	8	80%	11	73%	19	76%
S-Difficulty visiting with family						
No	1	10%	0	0%	1	4%
Sometimes	2	20%	4	26%	6	24%
Yes	7	70%	11	73%	18	72%
S-Difficulty hearing a whisper						
Sometimes	0	0%	1	6%	1	4%
Yes	10	100%	14	93%	24	96%
S-Difficulty hearing in restaurants						
No	1	10%	1	6%	2	8%
Yes	9	90%	14	93%	23	92%

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CHAPTER 3: ASSOCIATIONS AMONG HEARING LOSS, HOSPITALIZATION, READMISION, AND MORTALITY IN OLDER ADULTS: A SYSTEMATIC REVIEW [2]

Introduction

Hearing loss is a major public health concern with over 5% of the world population or approximately 360 million people having disabling hearing loss (NCID, 2017). A study using the National Health and Nutritional Examination Surveys (NHANES) demonstrated that the hearing loss prevalence increased from 44.9% for those between ages 60-69 to 89.1% for people ages 80 and older (Agrawal et al., 2011) (NCID, 2017; WHO, 2018). With an estimated population of over 80 million Americans over the age of 65 by 2030, there is a strong imperative to increase healthcare and service research among individuals with hearing loss (Knickman & Snell, 2002).

Hearing loss, currently the third most common chronic condition in elderly Americans, negatively affects individuals' physical, emotional, behavioral, and social functioning (Arlinger, 2003; Hogan, O'Loughlin, Miller, & Kendig, 2009; McKee, Stransky, & Reichard, 2018; Reuben, Mui, Damesyn, Moore, & Greendale, 1999; Simpson, Simpson, & Dubno, 2015, 2016). Hearing loss and its link to depression and dementia- independent of socioeconomic status, demographics and age, is well documented (Arlinger, 2003; F. R. Lin & Ferrucci, 2012; F. R. Lin et al., 2011). Research demonstrated relationships between hearing loss and multiple

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negative outcomes including social isolation/loneliness, depression, dementia, falls, cardiac disorders, arthritis, diabetes, and lower self-rated health (Donovan et al., 2016; Gopinath, McMahon, Burlutsky, & Mitchell, 2016; Hsu et al., 2016; Hull & Kerschen, 2010; F. R. Lin & Ferrucci, 2012; F. R. Lin et al., 2011; Mener, Betz, Genther, Chen, & Lin, 2013; Oh et al., 2014; Stam et al., 2014; Sung, Li, Blake, Betz, & Lin, 2016). Moreover, McKee and colleagues found that individuals with hearing loss are more likely to have one or more comorbidities (e.g., arthritis, cancer, diabetes, cardiovascular disease, emphysema, high blood pressure and stroke) compared to their hearing peers (McKee et al., 2018). Previous research also determined that those with multiple comorbidities and chronic conditions are more likely to be readmitted to the hospital within 30 days and are found to have longer and costlier hospitalizations than those without multiple comorbidities (Donze, Lipsitz, Bates, & Schnipper, 2013; Skinner, Coffey, Jones, Heslin, & Moy, 2016).

Hearing loss not only affects health outcomes, but also inpatient and outpatient healthcare experiences. Compared to their hearing peers, patients with hearing loss have double the risk of nonadherence, a potential risk factor for hospital readmission given that 10% of all hospital readmissions are related to patient nonadherence (Berg, Dischler, Wagner, Raia, & Palmer-Shevlin, 1993; Cardenas-Valladolid et al., 2010; Osterberg & Blaschke, 2005). Studies found that patients with hearing loss have 33% higher healthcare costs and 10% lower satisfaction regarding the quality of provider-patient communications compared to their hearing peers (Cardenas-Valladolid et al., 2010; Chang, Weinstein, Chodosh, & Blustein, 2018a; Mick, Foley, & Lin, 2014; Simpson et al., 2016).

Multiple factors, commonly seen among those with a hearing loss, were found to predict hospitalization, readmission, and mortality in several studies. Diabetes, heart disease, chronic kidney disease and chronic obstructive pulmonary disease all increased the risk for hospitalization (Frigola-Capell et al., 2013). Those with hypertension, heart disease, diabetes, chronic kidney disease and chronic obstructive pulmonary disease struggled with longer hospitalizations. Furthermore, Aliyu and colleagues found that older adults with self-rated poorer health status were three times more likely to be admitted to the hospital compared to those with good or excellent health status (Aliyu, Adediran, & Obisesan, 2003). Additionally, Aliyu and colleagues established a direct relationship between inability to perform activities of daily living (ADL) and admission to the hospital for older adults (Aliyu et al., 2003).

Patients with one or more prior readmissions have a higher likelihood of future readmission post index hospital stays compared to those with no prior readmissions (O'Connor et al., 2016). Additionally, patients whom are admitted via emergency room were found to have higher readmission rates (O'Connor et al., 2016). O'Connor and colleagues also found a significant association between the length of hospital stay and increased risk of readmission (O'Connor et al., 2016). Previous research demonstrates that patients with cardiovascular disorders (hypertension, heart failure, coronary artery disease, cardiac arrhythmias), kidney disease and diabetes have higher readmission rates (Donze et al., 2013; Frigola-Capell et al., 2013; O'Connor et al., 2016). Research also demonstrates that hospital readmission is linked to higher patient morbidity and mortality rates (Wong et al., 2011). Increased readmission rates are found to be correlated to an increase in comorbidities which has also been found to be an independent indicator of mortality (Oudejans, Mosterd, Zuithoff, & Hoes, 2012).

Purpose

Hearing loss is associated with a wide range of health conditions and poorer health outcomes. Yet, it is not as well understood how hearing loss may affect hospital-based outcomes and mortality in older adults. An evaluation and synthesis of studies examining relationships among hearing loss, hospitalizations, readmission and mortality may help to identify potential interventions to improve health outcomes in older adults with hearing loss aged 50 and older. Therefore, the purpose of this review is to systematically evaluate the current research about readmissions, hospitalizations, and mortality in older adults with hearing loss.

This review was guided by the following questions about hearing loss in older adults:

1.) What is the relationship between hearing loss and hospitalization?
2.) What is the relationship between hearing loss and readmission?
3.) What is the relationship between hearing loss and mortality?
4.) How are older adults screened for hearing loss?
    a. Relationships among screening, hospitalization, mortality and readmission.
5.) How does hearing aid use impact the relationships under study?
6.) Using the Newcastle-Ottawa scale, what is the quality of each reviewed study?

Methods

This systematic review was conducted following the guidelines suggested in Research Synthesis and Meta-Analysis (Cooper, 2016). The review incorporated studies that included factors associated with hearing loss, hospitalization, readmission, and mortality. The PRISMA flow diagram is presented in **Figure 1**. and the search terms are presented in **Table 1**.

Literature Search

As of October 2018, there are no published review protocol to study associations among hospitalization, readmission and mortality in older adults with hearing loss. Studies were identified by a search using search terms in the following search engine databases: Pubmed, Embase and CINAHL in October 2018. An experienced medical research librarian with expertise in systematic reviews assisted with the creation of the search strings used for each of the three databases with goals of employing a comprehensive search strategy while minimizing overlap. Two co-authors screened the articles and specifically sought studies that evaluated all three topics. Two authors screened all studies for eligibility at both the title/abstract and full text review stage using endnote. Disagreements in screening were resolved by a third author.

Inclusion/Exclusion Criteria

We included studies with populations aged 50 and older as the prevalence of hearing loss has been shown to increase after the age of 50 (Chia et al., 2007; Ferrite, Mactaggart, Kuper, Oye, & Polack, 2017; Wiley, Chappell, Carmichael, Nondahl, & Cruickshanks, 2008). Further, the American Speech-Language Hearing Association (ASHA) recommends hearing screening at least every 10 years, then every 3 years after the age of 50, thus potentially prompting earlier identification and intervention for this age group ("Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs," 2007). We also included studies that clearly stated methods of hearing measurement, hearing and hearing loss groups for comparison and clearly defined, non-aggregated outcomes.

We excluded studies with populations that consisted of the deaf, populations with specified hearing loss criteria such as occupational noise induced hearing loss only, and those who used cochlear implants. Our rationale for exclusion is that the deaf population's knowledge of disability resources, ability to advocate for themselves, and their access to information tends to differ from those who sustain hearing loss later in life (Iezzoni, Davis, Soukup, & O'Day, 2003; Kuenburg, Fellinger, & Fellinger, 2016). Further, the focus of our review is age-related hearing loss, not deaf, specified hearing losses such as noise induced hearing loss or use of cochlear implants as these populations often differ. We also excluded studies published before

2004 as the American Disability Act (ADA) amendment changes required all general assembly facilities to provide hearing accommodations such as assistive listening devices (Board, 2004). Exposure to assistive listening devices in public settings could result in a phenomenon called the mere exposure effect (Keller L Fau - Reeve & Reeve, 1998). This could increase awareness of hearing health in individuals with hearing loss and organizations, potentially increasing identification and intervention (Keller L Fau - Reeve & Reeve, 1998; Kimball et al., 2017). Moreover, use of assistive listening technologies, including hearing aids, has been shown to improve healthcare outcomes (Mahmoudi, Zazove, Meade, & McKee, 2018).

Our decision to exclude studies focused on long term, outpatient, and inpatient care settings was based on previous research which found mortality, readmission and hospitalization outcomes vary based on settings. For example, one study found that individuals discharged to long term settings are at higher risk for readmission and mortality, compared to those discharged to home (Merkow et al., 2015). Further, studies that recruited participants from inpatient settings were not included as hospitalization, readmission and mortality outcome would be less comparable across studies (Merkow et al., 2015). We also excluded studies that did not address our research questions or outcomes of interest, did not include subjects age 50 and older, did not specify the hard of hearing group, were not written in English, or were reviews, opinion pieces, and animal studies.

Data Extraction & Quality Assessment

A standardized data extraction table was used to collect data; purpose, sample size, sample demographics, study setting, hearing aid usage, attrition, outcome measures, hearing loss screening method, hearing loss definition, and time to follow up. Two authors independently extracted 20% of the included articles to reach consensus on types and depth of information extracted. Two authors independently assessed the quality of study of 20% of the articles included in the review. One single author extracted data and assessed the quality of the remaining studies independently. Disagreements were resolved by a third author.

The Newcastle – Ottawa Quality Assessment Scale was used to assess each study in this review (Lo, Mertz, & Loeb, 2014). This tool is widely utilized for assessing non-randomized studies in systematic reviews and meta analyses. Each of the studies was analyzed on eight items, categorized into three groups: study group selection, comparability of groups, and ascertainment of outcomes. Stars are awarded with the highest quality studies assigned nine stars and the lowest quality studies assigned zero stars. The comparability section was further revised to fit the quality assessment needs of our review. For example, a star was awarded if studies accounted for age and sex and second star (hat) was awarded if they accounted for cognitive function in their adjustments, and/or predictor/outcome measures. The quality assessment of each study is noted in Table 2.

Results

This search identified 15 studies that investigated the association between hearing loss and mortality, four studies that investigated the association between hearing loss and hospitalization, and one study investigating the association between hearing loss and readmission. As described in Table 2, nine studies were conducted in the United States of America, four were performed in Australia, and one each completed in Japan, India, Britain, Canada, Germany, Iceland and Taiwan. Six mortality studies, two hospitalization studies and one readmission study examined hearing loss alone as the primary risk factor of interest. In addition to hearing loss, seven mortality and two hospitalization studies also included other potential predictors such as vision, olfaction, cognition, multiple impairments, and dual sensory loss as primary risk factors of interest. The other two mortality studies considered hearing loss as a potential predictor of another association of interest (Feeny et al., 2012; Wang, Lin, & Chang, 2018).

Thirteen mortality studies, one hospitalization, and one readmission study were conducted solely in community dwellings for older adults. The remaining two mortality and three hospitalization studies did not specify (Chia, Wang, Rochtchina, & Mitchell, 2006; Contrera, Betz, Genther, & Lin, 2015; Genther, Frick, Chen, Betz, & Lin, 2013; Huddle, Deal, Swenor, Genther, & Lin, 2016; Liljas et al., 2016).

Fourteen mortality, four hospitalization and one readmission study included both males and females, and all studies were conducted on populations older than 50 years. One study focused solely on males (Liljas et al., 2016), and one study did not specify the genders included (Huddle et al., 2016). In all but four studies, females dominated the larger portion of the sample when both sexes were included (Contrera et al., 2015; Genther et al., 2013; Wahl et al., 2013; Wang et al., 2018). One study did not provide female and male ratios for their final sample size (Chia et al., 2006). Moreover, in seven studies where females dominated the overall sample size, more males had hearing loss compared to females in the sample (Amieva, Ouvrard, Meillon, Rullier, & Dartigues, 2018; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Genther, Betz, Pratt, Martin, et al., 2015; Karpa et al., 2010; Lopez et al., 2011; Yamada, Nishiwaki, Michikawa, & Takebayashi, 2011).

Multiple studies reported significant demographic differences between their hearing and hearing loss groups. Eight studies that provided characteristic comparisons between these two groups found that those with hearing loss tend to be significantly older, white and male with smoking, cardiac, stroke and depression history as well as poorer cognitive function, poorer self-rated health and lower education and income levels (Amieva et al., 2018; Chang, Weinstein, Chodosh, & Blustein, 2018b; Contrera et al., 2015; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Genther, Betz, Pratt, Martin, et al., 2015; Huddle et al., 2016; Karpa et al., 2010). One study indicated differences in race as well as average age, smoking history, myocardial infarction history and education level; however, they did not provide *p* values to indicate if these differences were significant (Liu, Cohen, Fillenbaum, Burchett, & Whitson, 2016). Three studies provided characteristics comparisons of those who survived and died (Agrawal et al., 2011; Schubert et al., 2017; Wang et al., 2018), two studies provided characteristics comparisons of dual sensory loss and unimpaired groups (Gopinath et al., 2016; Wahl et al., 2013), two studies provided characteristics comparisons of several hearing loss levels and unimpaired groups (Liljas et al., 2016; Yamada et al., 2011) , and single studies provided characteristics comparisons of two different age groups (18+ and 60+), and between sexes (Feeny et al., 2012; Lopez et al., 2011). Two studies did not report characteristic comparisons in their article (Chia et al., 2006; Huddle et al., 2016).

Out of all 20 studies, only one study reported that a power analysis was conducted, and that same study was completed with an adequate sample size (Agrawal et al., 2011). Nineteen studies had a sample size that well exceeded one thousand participants with an exception of one study. Wahl and colleagues used a much smaller sample size of 430 participants in their analysis and did not find statistical significance after minimal adjustments (Wahl et al., 2013).

What is the Relationship between Hearing Loss and Hospitalization?

Of the four studies included in this overall synthesis on hearing loss, 3 studies found that hearing loss was significantly associated with incident (first) hospitalizations and number of annual hospitalizations. This association was independent of demographic (age, sex, race, education, income), and cardiovascular factors (hypertension, stroke, smoking, CVD), as well as diabetes, and cognitive function (Genther, Betz, Pratt, Martin, et al., 2015; Genther et al., 2013; Huddle et al., 2016). Furthermore, Genther and colleagues also looked at hearing loss and its association to length of hospital stay, but this resulted in non-significant findings (Genther, Betz, Pratt, Martin, et al., 2015). One study did not find significant associations between hearing loss and rate of annual hospitalizations after adjustments for age and sex, and this same study did not provide a crude odds ratio (Chia et al., 2006). Some of the articles reviewed reported on aspects of the same study. For example, articles by Genther and colleagues (2013) (Genther et al., 2013) and Huddle and colleagues (2016) (Huddle et al., 2016) reported different parts of the quantitative study investigating the association among sensory impairment, hospitalizations and burden of disease. Additionally, Genther et al. defined hearing loss as >25 decibels (dB) and found significant associations. Huddle et al. investigated dual sensory loss and defined their hearing loss groups as mild (>25-39dB) and moderate/severe (>40dB). This research team found significance in incidence and length of hospitalization only in those with moderate to severe hearing loss (Huddle et al., 2016). Furthermore, in a separate study, a significant association was established among mild and moderate to severe hearing loss and hospitalizations (Genther, Betz, Pratt, Martin, et al., 2015).

How are older adults screened for hearing loss. All four studies investigating hospitalization utilized audiometric screening. One study stated the pure tone air conduction audiometry was conducted in a sound treated booth by audiometer and examiner (Genther, Betz, Pratt, Martin, et al., 2015). The three remaining studies reported utilizing a database which indicated pure tone air conduction audiometry was used. There were no specifications as to whether a trained audiologist was involved in the screening in any of the studies.

Hearing loss definition. All four of the studies incorporated clear definitions for their inclusion criteria of hearing loss, however, they differed across studies making comparisons difficult. Two studies defined hearing loss as mild >25dB and moderate/severe >40dB. Two studies defined any hearing loss as >25dB.

Hearing loss severity. Two studies found that moderate to severe hearing loss results in a higher risk for hospitalizations compared to mild hearing loss (Genther, Betz, Pratt, Martin, et al., 2015; Huddle et al., 2016). Two studies aggregated all levels of hearing loss to any hearing loss >25dB (Chia et al., 2006; Genther et al., 2013).

How does hearing aid use impact the relationships under study. One of the four studies included hearing aid use in the analysis. Though hearing aid use had no significant association with incident hospitalization and rate of annual hospitalization, the utilization of hearing aids was found to shorten the length of hospitalizations (Genther, Betz, Pratt, Martin, et al., 2015).

Outcome Measurement. All four studies assessed the outcomes through participant self-report and did not include objective measures.

Using the Newcastle Ottawa Scale, what is the quality of each reviewed study. When evaluated by the Newcastle Ottawa Quality Assessment scale, one study received 8 points and three studies received 7 points. Details provided in Table 2. Newcastle-Ottawa Quality Assessment Scale.

What is the Relationship between Hearing Loss and Readmission?

One study was identified investigating hearing loss and its association to readmission (Chang et al., 2018b). This study found an increased risk of readmission in those who reported trouble communicating with their providers, compared to those who reported no trouble, before and after all adjustments. This study reported that those who had trouble communicating had an average of 32% greater odds of readmission compared to their hearing peers. Chang et al. used self-reported hearing screening methods and provided a clear definition for their inclusion criteria. This study used a dataset for their outcome measures and received in a quality assessment score of 6 stars. Details provided in Table 2. Newcastle-Ottawa Quality Assessment Scale.

What is the Relationship between Hearing Loss and Mortality?

Twelve of the fifteen studies provided the following hazard ratios (HR) or odds ratios (OR); crude, univariate, and minimal adjustments (age and/or gender), which indicated significant associations between hearing loss and mortality (Agrawal et al., 2011; Contrera et al., 2015; Feeny et al., 2012; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Gopinath et al., 2013; Karpa et al., 2010; Liljas et al., 2016; Mitoku, Masaki, Ogata, & Okamoto, 2016; Schubert et al., 2017; Wahl et al., 2013; Wang et al., 2018; Yamada et al., 2011). Amieva et al. and Liu et al. did not provide a crude or unadjusted HR or OR, and Lopez et al. provided an insignificant crude HR (Amieva et al., 2018; Liu et al., 2016; Lopez et al., 2011). Of these twelve studies, three studies demonstrated significant associations between hearing loss and mortality after adjusting for all covariates (Agrawal et al., 2011; Fisher et al., 2014; Gopinath et al., 2013). Agrawal et al. found significance only in those aged 70 and older. Fisher et al. found significance in cardiovascular mortality in men only. Gopinath et al. found significant associations in those with mild hearing loss only. In three studies, men and older persons were more likely to have hearing loss and higher mortality rates when compared to the opposite sex and younger study participants (Agrawal et al., 2011; Feeny et al., 2012; Fisher et al., 2014).

Some of the articles presented results from the same study. For example, the articles by (Gopinath et al., 2013) and (Karpa et al., 2010) reported different parts of the quantitative study investigating the association between sensory impairment and mortality. Karpa et al. primarily looked at hearing loss as a predictor, included a structural equation model, and defined hearing loss as mild >25-45 db and moderate to severe as >45 dB. The sample included those age 50 and older, and the protocol had an 8 year follow up period. In contrast, Gopinath et al. primarily looked at dual sensory loss as a predictor of mortality, defined hearing loss as mild >25 – 40 dB and moderate to severe as >40 dB, included those aged 55 and older, and had a follow up period of 10 years.

Covariates. Many factors influenced the relationship between hearing loss and mortality. Common factors included, but were not limited to, age, gender, cognitive function, mobility, self-rated health, and comorbidities including cardiac factors (Agrawal et al., 2011; Amieva et al., 2018; Contrera et al., 2015; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Karpa et al., 2010; Schubert et al., 2017; Yamada et al., 2011). Age and gender were considered to have large confounding effects in several studies. For example, in Agrawal et al., significance was only found in those aged 70 and older after adjustments for all covariates (Agrawal et al., 2011). There was no statistical significance in other age groups after adjusting for all covariates. Two other studies found similar results with Feeny et al. finding significance in males and those over 70 years, and Fisher et al. finding significance in males only (Feeny et al., 2012; Fisher et al., 2014).

Evidence suggests that the relationship between hearing loss and mortality can be attenuated with further adjustments, including cardiovascular factors. For example, one study, when adjusted for all covariates excluding blood vessel thickening cardiac factors such as; interleuken, intermedia thickness, and C reactive protein, indicated a significant relationship between hearing loss and mortality (Schubert et al., 2017). When adjusting for all covariates, including the aforementioned cardiac covariates, this study demonstrated no significance, therefore indicating that some cardiac factors could have potential confounding effects (Schubert et al., 2017). Cardiovascular factors were also found to influence the association in three other studies. Fisher et al. found cardiovascular disease related mortality, but not all-cause mortality, to be significant in men with hearing loss (Fisher et al., 2014) and in Contrera et al. the relationship between hearing loss and mortality was attenuated when gender, race, education and cardiovascular factors were adjusted. Furthermore, Feeny et al. also indicated significant associations between hearing loss and mortality in those with chronic conditions associated with mortality, including hypertension, chronic bronchitis, diabetes, cancer, stroke, and heart disease.

Cognitive function, walking ability/mobility, and self-rated health were found to be potential mediators in two studies. For example, one study assessed whether hearing loss had a direct or indirect association to mortality by utilizing the structural equation modeling analysis (Karpa et al., 2010). This study indicated that hearing loss had an effect only if there was a mediating factor such as walking mobility, cognitive function, and self-rated health. Another study found similar results indicating that cognitive function and mobility were strong mediators (Genther, Betz, Pratt, Kritchevsky, et al., 2015). Evidence suggests that vision and cognitive function may also have confounding effects (Liu, Cohen, Fillenbaum, Burchett, & Whitson, 2015; Yamada et al., 2011). For example, six studies suggest concurrent sensory impairments such as hearing loss/vision loss or hearing loss/cognitive impairment significantly increased mortality risk (Amieva et al., 2018; Fisher et al., 2014; Gopinath et al., 2013; Karpa et al., 2010; Liu et al., 2015; Lopez et al., 2011). Cognitive function was also found to be a significant independent risk factor to mortality in two other studies in our review (Feeny et al., 2012; Liu et al., 2015).

How are older adults screened for hearing loss. The use of different assessment methods to measure hearing loss made comparisons among the reported findings difficult. In the 15 studies, seven used audiometric screening, one used whisper, Weber and Rinne tests (Agrawal et al., 2011; Contrera et al., 2015; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Gopinath et al., 2013; Karpa et al., 2010; Schubert et al., 2017; Wahl et al., 2013), six studies used self-report, and one used the Health Utilities Index 3 (HUI3) instrument for assessing hearing loss (Amieva et al., 2018; Feeny et al., 2012; Liljas et al., 2016; Liu et al., 2015; Lopez et al., 2011; Wang et al., 2018; Yamada et al., 2011).

Five of the seven studies using audiometric screening explained their testing methods as pure tone air conduction audiometry in sound treated booth (Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Gopinath et al., 2016; Karpa et al., 2010; Schubert et al., 2017). One study included both air and bone conduction (Schubert et al., 2017), and one study added that an audiometer and examiner were involved (Genther, Betz, Pratt, Kritchevsky, et al., 2015). Of these studies, only one reported that a trained audiologist was involved in the screening process (Karpa et al., 2010). The remaining two studies did not provide details as to how the audiometric tests were conducted (Contrera et al., 2015; Wahl et al., 2013).

Seven out of seven audiometric screened (Agrawal et al., 2011; Contrera et al., 2015; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Gopinath et al., 2013; Karpa et al., 2010; Liljas et al., 2016; Schubert et al., 2017; Wahl et al., 2013), one Weber/Rinne/whisper (Agrawal et al., 2011), and three of six self-report screened studies (Liljas et al., 2016; Wang et al., 2018; Yamada et al., 2011) indicated significant associations between hearing loss and mortality prior to all adjustments. The HUI3 study also found significance (Feeny et al., 2012). After adjustments, three out of eight audiometric and whisper, Weber, Rinne (Agrawal et al., 2011; Fisher et al., 2014; Gopinath et al., 2013), and one out of six self-report (Wang et al., 2018) indicated significant associations between hearing loss and mortality.

Hearing loss definition. Several studies defined hearing loss differently making comparisons among the reported findings difficult. Seven studies which assessed hearing loss using audiometry often presented different definitions for hearing loss. For example, studies defined hearing loss as; any hearing impairment >25dB (Genther, Betz, Pratt, Kritchevsky, et al., 2015; Schubert et al., 2017), and mild >25dB – 40dB and moderate to severe loss >40dB (Contrera et al., 2015; Gopinath et al., 2016). One study defined hearing loss as mild >25dB and moderate to severe >45dB (Karpa et al., 2010). The other two studies using audiometry defined hearing loss as >35dB (Fisher et al., 2014; Wahl et al., 2013). Four of six studies using self-report and one HUI3 evaluations indicated clear definitions for their inclusion criteria (Feeny et al., 2012; Liu et al., 2015; Lopez et al., 2011; Wang et al., 2018; Yamada et al., 2011). The remaining three of the fifteen studies did not include a clear definition for their inclusion criteria of hearing loss (Agrawal et al., 2011; Amieva et al., 2018; Liljas et al., 2016).

Hearing loss severity. Five studies found that as the severity of the hearing loss increased, the risk of mortality increased. In other words, moderate to severe hearing loss had stronger associations to mortality than mild and no hearing loss (Contrera et al., 2015; Feeny et al., 2012; Fisher et al., 2014; Wahl et al., 2013; Yamada et al., 2011) Interestingly, one study found significant associations in mild, but not moderate to severe hearing loss (Gopinath et al., 2013).

How does hearing aid use impact the relationships under study. Five out of the 15 studies included hearing aids. Two of these studies found hearing aid use made a significant difference in mortality risk (Fisher et al., 2014; Liljas et al., 2016). Fisher et al. compared hard of hearing participants with and without hearing aids and found a significant difference in all cause and cardiovascular mortality between the two groups. Additionally, another study found that those with hearing loss who used hearing aids were on par with their hearing peers in terms of mortality (Liljas et al., 2016). Three studies did not find significant differences in hearing aid use and mortality (Amieva et al., 2018; Genther, Betz, Pratt, Martin, et al., 2015; Yamada et al., 2011). These studies used self-reported measures for either hearing loss and/or hearing aid use. Though Amieva et al. did not find significant differences in mortality for those with hearing loss whom did or did not wear hearing aids, they did find that hearing aid users fared better than non-users and were on par with hearing counterparts with respect to risk of depression, disability and dementia (Amieva et al., 2018).

Outcome Measures. Fourteen of the 15 studies investigating mortality included measurements such as death certificates, death indexes, registrars and databases. One measured by annual contact with participants and checking local obituaries (Schubert et al., 2017).

Using the Newcastle Ottawa Scale, what is the quality of each reviewed study. When evaluated by the Newcastle Ottawa Quality Assessment scale, five studies received 9 points, four studies received 8 points, four studies received 7 points, and two studies received 6. Details provided in Table 2. Newcastle-Ottawa Quality Assessment Scale.

Discussion

In this systematic review of twenty studies, there is support that hearing loss is potentially associated with increased risk of hospitalization, readmission, and mortality. However, due to the minimal number of studies investigating hospitalization and readmission, inconsistent methods of hearing loss measurements, varied definitions for hearing loss, and conflicting findings in several studies, there is insufficient evidence to indicate that hearing loss is an independent predictor of hospitalization, readmission, or mortality. In the majority of the studies, factors such as age, sex, cognitive function, walking ability/mobility, self-rated health, and cardiac disorders had confounding effects on the relationship. Sample size also appeared to have an impact as one study which had a substantially smaller sample size compared to the others resulted in non-significant findings after minimal adjustments possibly due to power (Wahl et al., 2013). Several studies that indicated any significant associations in the relationships under study shared characteristics such as an older sample population (70+), longer follow up periods, stratified by hearing loss severity, and conducted objective screening measures such as audiometry for hearing loss (Agrawal et al., 2011; Contrera et al., 2015; Feeny et al., 2012; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Genther, Betz, Pratt, Martin, et al., 2015; Genther et al., 2013; Gopinath et al., 2013; Huddle et al., 2016; Karpa et al., 2010; Liljas et al., 2016; Mitoku et al., 2016; Schubert et al., 2017; Wahl et al., 2013; Wang et al., 2018; Yamada et al., 2011).

Three of the 4 studies found significant relationships between hearing loss and hospitalizations. In Huddle et al, only moderate to severe hearing loss was associated to increased hospitalization. This finding is not surprising, as most studies that stratified by hearing loss severity indicated that the worse the hearing loss, the higher risk of negative outcomes including hospitalization and mortality. In contrast, Genther et al. suggested that mild hearing loss in addition to moderate to severe hearing loss is associated to incident hospitalizations and a greater number of annual hospitalizations (Genther, Betz, Pratt, Martin, et al., 2015). This may be due to a larger mild hearing loss sample size in Genther et al. One study did not find a significant association between hearing loss and hospitalization after adjusting for age and sex (Chia et al., 2006). A possible reason for this is that this study aggregated hearing loss severity to any hearing loss >25dB which could have resulted in less accurate findings compared to if they had stratified by severity. Additionally, this study measured and stratified by impairments, including cognitive impairments, whereas Genther et al, and Huddle et al. did not report how cognitive function was accounted (Genther et al., 2013; Huddle et al., 2016). It is important to report how cognition is accounted for in these studies as significant relationships among hearing loss, cognitive impairment and hospitalizations has been established (Bynum et al., 2004; Feng, Coots, Kaganova, & Wiener, 2014; Gurgel et al., 2014; Han, Tang, & Ma, 2018; Hewitt, 2017; P. J. Lin, Fillit, Cohen, & Neumann, 2013). Though these four studies provide insight to this phenomenon, more studies should be conducted to further investigate this relationship.

The one study included in our review did find a significant relationship between hearing loss and readmission. It is important to note that this study used subjective screening methods for hearing loss and did not report how they accounted for cognitive function in their analyses. This study also did not account for patient disposition (patient discharge location). This is important as patients whom are discharged to long term care facilities have higher risk of readmission compared to those discharged to home (Merkow et al., 2015). Since only one study was found, more studies are highly needed to assist with better understanding of this phenomenon.

Multiple studies suggest that those with hearing loss had higher mortality risk compared to hearing peers. However, these studies indicated that hearing loss may not independently increase mortality risk, but the negative effects of hearing loss can. For example, similar to previous research, compared to their hearing peers, those with hearing loss were found to be at higher risk for depression, diabetes, high cholesterol, and falls (Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Karpa et al., 2010; Yamada et al., 2011). Lower self-rated well being also appeared to be linked to hearing loss (Yamada et al., 2011). All of these factors have been found to be individually associated to hearing loss, and mortality, which we will discuss in this review.

Two studies in our review indicated that cognitive function, walking ability/mobility, and self-rated health were possible mediators (Genther, Betz, Pratt, Martin, et al., 2015; Karpa et al., 2010). Several studies in our review also investigated these three potential mediators as predictors or outcomes. For example, two studies indicated cognitive impairment to be significantly associated to mortality, and three studies found hearing loss to be significantly associated to cognitive impairment (Amieva et al., 2018; Feeny et al., 2012; Karpa et al., 2010; Liu et al., 2015; Lopez et al., 2011). This is not surprising as previous research has demonstrated a strong relationship between hearing loss and cognitive function (Gurgel et al., 2014; Han et al., 2018; Hewitt, 2017; F. R. Lin et al., 2011; Liu et al., 2016; Wingfield & Peelle, 2012, 2015) and cognitive function to mortality (Frisoni, Fratiglioni L Fau - Fastbom, Fastbom J Fau - Viitanen, Viitanen M Fau - Winblad, & Winblad, 1999; Lee et al., 2018; Perna et al., 2015). Genther et al. also looked at self-rated health as an outcome and found a significant association (Genther et al., 2013). Self-rated health has been linked to both hearing loss and mortality in previous research (Heistaro, Jousilahti P Fau - Lahelma, Lahelma E Fau - Vartiainen, Vartiainen E Fau - Puska, & Puska, 2001; Nery Guimaraes et al., 2012). Mobility influencing the relationship between hearing loss and mortality in two of our studies in our review is not surprising as six other studies in our review that looked at mobility, ADL, and falls, as predictors or outcomes, found significant associations (Amieva et al., 2018; Feeny et al., 2012; Liljas et al., 2016; Lopez et al., 2011; Wang et al., 2018; Yamada et al., 2011). Previous research has demonstrated an association among hearing loss, mobility, ADL, and falls (Agmon, Lavie, & Doumas, 2017; Girard et al., 2014; Jiam, Li, & Agrawal, 2016; Sogebi, Oluwole, & Mabifah, 2015).

Additionally, associations have been established among mobility, ADL, falls, and mortality (Khokhar et al., 2001; Seitz et al., 2014).

Covariates such as cardiovascular factors influenced the relationship between hearing loss and mortality in several studies in our review. The relationship between hearing loss and cardiovascular risk has been well established in previous research (Tan et al., 2018; Wattamwar et al., 2018). One explanation for this could be that there are known correlations between low HDL levels and hearing loss thus increasing the risk for cardiovascular disease (Park, Johnson, Shea Miller, & De Chicchis, 2007). Furthermore, cardiovascular factors are known to be strongly associated to mortality (Wattamwar et al., 2018).

Although several studies suggest possible mediators and confounders influencing the relationship between hearing loss and mortality, more research should be conducted to assess whether the association is direct or indirect and what mediators and confounders have the strongest associations. Future studies could use the structural equation modeling analysis demonstrated in Karpa et al. to examine the relationships. Determining which common factors greatly increase the risk of adverse outcomes for this patient population could assist with prioritizing and tailoring care.

Evidence in our review also suggests that there are significant differences in sex, age, and certain comorbidities between those with and without hearing loss. Therefore, special attention should be paid to the age and sexes of the sample. For example, in few studies, the results of samples with older adults and males when aggregated yielded different results than when stratified (Agrawal et al., 2011; Feeny et al., 2012; Fisher et al., 2014). In one study, males and combined sexes were found to be significantly associated to CVD mortality (Fisher et al., 2014). However, females individually did not reach statistical significance. Males inflated the overall result indicating that all sexes with hearing loss have higher CVD mortality when that was not the case for this study. Similarly, Agrawal et al, and Feeny et al. also indicated significance after stratification for age and sex. These findings are no surprise as previous research has established strong associations among hearing loss, aging, and sex. Evidence in previous research suggests that the prevalence of hearing loss increases significantly with age and in males (Im et al., 2018; Li, Zhao, Hoffman, Town, & Themann, 2018; Walling & Dickson, 2012). Due to the significant differences stratification for age and sex made for some of these studies, stratification by age and sex in future analyses is recommended to lessen the chances of missing pertinent associations.

Though the use of different assessment methods to measure hearing loss made comparisons among the reported findings difficult, this review can shed some light on this matter. Five out of seven studies using self-report screening methods found statistical significance in all relationships under study compared to ten out of eleven audiometry, one Weber/Rhine/whisper tests and one HUI3 screening study with none or minimal adjustments (age and/or sex). Research indicates that hearing loss is often underestimated and underreported by older adults (Ramkissoon & Cole, 2011). As a consequence, their self-reported screening results did not match with their audiometric testing (Ramkissoon & Cole, 2011). Further, it is common for older adults to delay seeking hearing healthcare for 10 to 15 years (Morris, Lutman, Cook, & Turner, 2013). This phenomenon is possibly due to lack of awareness of loss of hearing due to slow progression of hearing loss. Moreover, self-reported screenings heavily rely on the patients' knowledge, candor, and acceptance of hearing status which can impact identification. (Arlinger, 2003). Relying on subjective screening tools such as self-report is not ideal, as it could result in predictor contamination in the control/reference group.

Because objective screening methods appears to have made a difference in whether or not significance was found in these associations under study, it is highly recommended that screening tools such as audiometry, Weber and Rinne, finger rub, or whisper tests are conducted in future hearing screenings. It is important to note that whisper, Weber and Rinne tests may not always be reliable, as there are many variables that can affect the test results such as environmental noise, cerumen occlusion and ear infections (Lasak, Allen, McVay, & Lewis, 2014). Furthermore, if these tests are not feasible, another recommendation is the utilization of screening tools such as the hearing handicap inventory for the elderly screening tool (HHIE-S) (Demers, 2013).

Studies in our review defined hearing loss differently which made comparisons among studies difficult. Evidence in our review suggests that the more severe the loss of hearing, the higher risk of hospitalization and mortality. Seven of the twenty studies indicated that moderate to severe hearing loss had stronger associations to these negative outcomes compared to those with mild or no hearing loss (Contrera et al., 2015; Feeny et al., 2012; Fisher et al., 2014; Genther, Betz, Pratt, Martin, et al., 2015; Huddle et al., 2016; Wahl et al., 2013; Yamada et al., 2011). One study found stronger associations in mild hearing loss compared to moderate to severe hearing loss (Gopinath et al., 2013) and one study had mixed results (Karpa et al., 2010). Gopinath et al. and Karpa et al. findings could be due to the larger mild hearing loss group compared to moderate to severe hearing loss group and the varied definitions of hearing loss in both studies. The rest of the studies either had insufficient data to identify mild, moderate and severe hearing loss, or they aggregated hearing loss in their analyses. Research suggests that aggregation can result in loss of valuable information, therefore aggregation of hearing loss severity could result in missing pertinent associations or inflating findings depending on sample and design (Pollet, Stulp, Henzi, & Barrett, 2015).

Despite the prevalence of and the known negative outcomes associated with hearing loss, it is often overshadowed by other pressing health conditions in interactions with health care providers (Li-Korotky, 2012). Hearing loss may not be recognized by individuals as it is often slow to progress, subsequently resulting in a delay in seeking hearing healthcare (Arlinger, 2003; Morris et al., 2013). The lack of individual identification, acceptance, knowledge, or ability to advocate regarding their hearing loss could result in disuse of appropriate screenings and accommodations. For example, one study in our review that found no significant association between hearing aid use and mortality risk recognized that only 25% of the hearing loss study population were aided resulting in a small aided population size of 59 participants (Yamada et al., 2011). The small hearing aid cohort, self-reported exposure measures, and a shorter follow up time of 3 years could have attenuated the relationship between hearing aid use and mortality in this study (Yamada et al., 2011). Furthermore, the fact that only 25% of patients with hearing loss used hearing aids in this study is not surprising, as research suggests that among adults aged 70 and older with hearing loss who could benefit from hearing aids, fewer than one in three have ever used them (NIDCD, 2016). Another common reason for hearing accommodation disuse is the lack of insurance coverage and high cost of hearing aids (Donahue, Dubno, & Beck, 2010). Hearing aids and hearing healthcare services being cost prohibitive for older adults may highlight the importance for future studies to put more emphasis on socioeconomic status (income, education and occupation) in adjustments for more accurate results.

There is strong evidence to suggest that technological accommodations such as hearing aids may be an important quality improvement intervention, as their use has been associated with improved healthcare experiences and outcomes (Cook & Hawkins, 2007; Kimball et al., 2017; Kochkin, 2007; Mahmoudi et al., 2018; Pichora-Fuller & Singh, 2006). Studies in our review suggest that hearing aid use may be associated with decreased risk of depression, length of hospitalizations, ADL deficiency and mortality (Amieva et al., 2018; Fisher et al., 2014; Genther, Betz, Pratt, Martin, et al., 2015; Liljas et al., 2016). It is important to note that the two studies that found significance in the relationship between hearing loss and mortality adjusted for minimal to no socioeconomic factors. For example, Fisher et al. did not adjust for any socioeconomic factors, and Liljas et al adjusted for social class only. As aforementioned, adjusting for socioeconomic factors is important as hearing aids are expensive and often cost prohibitive for older adults (Donahue et al., 2010).

The importance of prioritizing hearing accommodations is highlighted in a recent study investigating the association between hearing aid use and use of healthcare services. This study found that patients who used hearing aids had significantly less emergency room visits, hospitalizations, and length of hospitalizations compared to those who did not use hearing aids. Patients who used hearing aids also had significantly increased physician office visits indicating better management of care which may subsequently be related to the decrease in emergency room visits and hospitalizations (Mahmoudi et al., 2018). None of the studies assessing mortality or hospitalizations as an outcome measure conducted power analysis for the hearing aid cohort size, as they did not investigate hearing aid use as a primary variable. Therefore, further research with a focus on hearing aid use and use of other accommodations is recommended to assess the relationship between use of accommodations and adverse health outcomes such as hospitalization, readmission, and mortality.

All studies received a quality assessment score of at least 6 stars and those who shared similar scores, shared similar characteristics. For example, studies that were awarded the highest number of stars used audiometric testing to screen for hearing loss, accounted for cognitive function, and did not have self-reported outcome measures. Studies with the lowest stars in our review (6 stars), shared characteristics such as; self-reported hearing screening, did not account for cognitive function, and used self-reported outcome measures.

Future Research

Hearing loss and its association with various morbidities, hospitalization and mortality has been well studied. Although the associations among hearing loss, hospitalization and readmission is not as heavily studied as morbidities and mortality, the four hospitalization and one readmission study in this review do give valuable insight on the phenomenon. Due to the retrospective and cross-sectional nature of the majority of the hospitalization and readmission studies, further investigations using prospective longitudinal cohort design is recommended. Due to the large differences in number of studies assessing these three outcomes, future research should prioritize investigating the relationship among hearing loss, hospitalization and readmission. Future research should also prioritize investigating if early identification and effective management of age-related hearing loss, whether through screening, hearing aids, assistive listening devices or other methods, could decrease adverse health outcomes such as hospitalizations, readmission and mortality. It is recommended that future studies screen for hearing loss using audiometry, adhere to established audiometric definitions of hearing loss (i.e., World Health Organization classification of hearing impairment), accurately measure and control for common confounders, abstain from aggregating hearing loss severity and stratify for gender and age to optimize results.

Limitations

Several limitations in this review should be considered. Only 20 studies met the inclusion criteria, and of those, only four looked at hospitalization and one looked at readmission as an outcome. We observed several variations across all studies making comparisons of study findings difficult. Variations occurred in the populations studied, how hearing loss was screened and defined, how hospitalization and mortality were assessed, and whether other common confounding factors were considered in the inclusion/exclusion criteria or analyses. Several studies which provided characteristic comparisons between hearing loss and non-hearing loss groups indicated significant differences between the two groups. Eleven studies did not provide characteristic comparisons between hearing loss and non-hearing loss groups. Only 11 of the 20 studies used gold-standard audiometry to identify and define hearing loss. Any error in the classification of hearing loss status may result in predictor contamination in the control group, and subsequently bias observations toward the null hypothesis. Lastly, there was only one study in our review that looked at hearing loss and readmission which did not account for patient disposition (patient discharge location). This is important as patients whom are discharged to long term care facilities have higher risk of readmission compared to those discharged to home (Merkow et al., 2015). Since only one study was found looking at readmission, more studies are necessary to assist with better understanding of this phenomenon.

Lessons Learned

Several revelations were identified in the process of this systematic review. First, two studies collected prospective longitudinal data. However, no studies investigated the impact of hearing loss severity and change of hearing loss severity on health outcomes over time. The need for further research in a prospective longitudinal design is paramount to assist with further understanding of this phenomenon such as what the largest challenge is for achieving better health outcomes in these patients. For example, how does hearing loss over the years impact these outcomes? Also, how does hearing loss severity worsen and subsequently impact these outcomes over time? It is recommended that hearing reassessments as well as cognitive reassessments every 3 years minimum should be conducted in these studies to better understand the implications of hearing loss. We also need to better understand where is the biggest hurdle for this population? Is it lack of accommodations or lack of patient activation or perhaps something else? Second, though the focus of this systematic review was the association between hearing loss and health outcomes, it was clear that few studies included hearing accommodation in their analyses. For example, only 6 of the 20 studies incorporated hearing aid use in their analyses and none of these 6 studies adjusted for socioeconomic status (education, income, occupation). This indicates a strong need for incorporating hearing accommodation use in these types of studies as previous research has found that hearing aid use can lead to improved health outcomes. Third, few studies also included mobility/walking ability in their analyses and hearing loss has been found to be closely associated with falls in several studies. Our third paper also indicates higher readmissions in those with hearing loss and with primary 30-day readmission diagnoses closely that are associated to falls. This indicates a strong need for future studies investigating this phenomenon to consider adjusting for mobility/walking ability in their analyses.

Conclusion

This systematic review provides support that hearing loss appears to be associated with statistically significant increased risk of hospitalization, readmission, and mortality. Investigating specific predictors and the relationships among hospitalizations, readmission, and mortality will help to inform us of how to better care for and educate patients with hearing loss in healthcare settings. Accomplishing this could help to inform which morbidities or interventions need to be prioritized for better patient outcomes.

Table 1. Search Terms

Database	Search String	Restrictions
PubMed	(Presbycusis[tw] OR Hearing loss*[tw] OR Hearing impair*[tw] OR Hard of hearing[tw]) AND (Elderly[tw] OR Geriatric[tw] OR Older adult*[tw] OR Aged[mesh]) AND (Mortality[mesh] OR mortalit*[tw] OR readmission*[tw] OR hospitalization* [tw])	
CINAHL	(Presbycusis OR "Hearing loss" OR "Hearing impairment" OR "Hard of hearing") AND (Elderly OR Geriatric OR "Older adult" OR "Older adults" OR (MH "Aged+")) AND ((MH "Mortality+") OR mortalit* OR readmission* OR hospitalization*)	English, Publications after 2004 Peer Reviewed
Embase	presbycusis:de,ti,ab OR 'hearing loss':de,ti,ab OR 'hearing impairment':de,ti,ab OR 'hard of hearing':de,ti,ab AND (elderly:de,ti,ab OR geriatric:de,ti,ab OR 'older adult':de,ti,ab OR 'older adults':de,ti,ab OR 'aged'/exp) AND ('mortality'/exp OR mortalit*:de,ti,ab OR readmission*:de,ti,ab OR hospitalization*:de,ti,ab)	English only, Publications after 2004

Figure 1: PRISMA

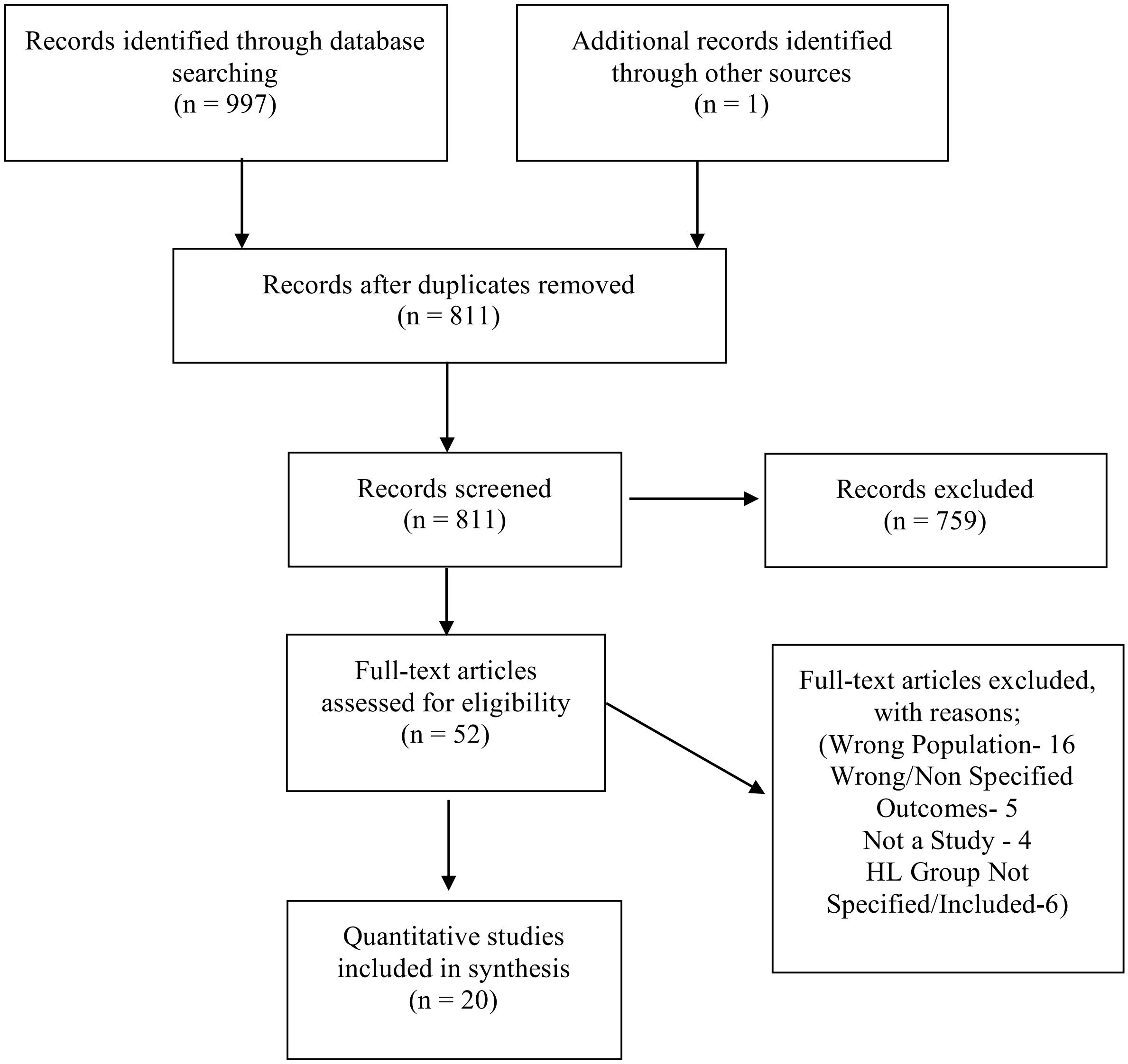

Table 2. Study Findings

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Mortality							
Hazard Ratio							
Agrawal et al. (2011)	Prospective population based cohort Primary + blindness	Rural north India – Ballabgargh Block, Haryana. N: 1,422 Age: 60 + M: N = 683 F: N= 739 HL (n= 210) UI (n= 1,078) Rural community dwelling Participation rate: 100%	3 days to 567 days Median: 518 days Local death registrars	Whisper, Webber and Rhine Does not state clear definition	*Age, sex, literacy, hypertension, diabetes, coronary artery disease, stroke, orthopedic impairment, dressing, feeding and self-rated health*.	**Crude:** 2.4 (1.55 – 3.7) **(S)** **Hypertension, diabetes, coronary artery disease, stroke, orthopedic impairment, dressing, feeding and self-rated health only:** 2.38 (1.53- 3.69) **(S)** **All adjustments:** >70 years: 2.13 (1.29-3.54) **(S)**	8

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Amieva et al. (2018)	Prospective longitudinal population based cohort Primary	Bordeaux, France N=3,588 Age: 65+ M: N = 1,507 F: N = 2,081 HL: 1,289 UI: 2,290 Mean age: 75.3 Mean age of HL: 77-79 Hearing aid users: 176 Community dwelling Participation rate: 95%	25 years 12 follow up visits total with reassessments of cognitive and hearing function Family, physicians and civil state records	Self-Report “do you have trouble hearing?” 1)No trouble 2)Trouble in background noise 3)Major trouble 4)use HA? Not clear which answers were considered to be HI	Age, sex, educational level, and number of comorbidities (hypertension, myocardial infarction, angor, diabetes, dyspnea, history of stroke and smoking)	No crude HL HR HL: .99 (.92 - 1.07) HL with no HA: 0.99 (0.92 - 1.07) HL with HA: 1.03 (0.87 - 1.21)	7
Contrera et al. (2015)	Retrospective cohort Primary	USA – National Database N: 1,666 Age: 70 + M: N=847	NHANES (2005- 2006 & 2009-2010) (Mortality 2011) Death certificates	Audiometry UI: (<25 dB) Mild: (>25-<40) Mod/Sev: (> 40 dB) PTA	*Age*, sex, education, race, hypertension, diabetes, cardiovascular disease, smoking, and stroke	**Base:** Mild: 1.54 (1.06 – 2.25) **(S)** Mod/severe: 2.30 (1.64 – 3.27) **(S)** **Age only:**	8

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
		F: N = 819 HL (mild (n=589) mod/sev (n=550)) UI (n=527)		Database entry		Mod/sev: 1.54 (1.08 – 2.18) **(S)**	
Feeny et al. (2012)	Retrospective population based cohort Secondary + vision, speech, ambulation, dexterity, emotion, cognition and pain.	Canada N: 3,575 (60+) Age: 60 + M: (n =1,446) F: (n =2,129) Community dwelling	12 years Interviewed every 2 years with HUI3? Canadian Vital Statistics Database	Health Utilities Index Mark 3 (HUI3) {Interclass Corr Coeff 0.88) Normal (level 1) to most severe (level 6) Any HL (levels 2-6)	Age, sex, house hold income, education, marital status, hypertension, diabetes, coronary artery disease, cancer, stroke, cancer, bronchitis, heart disease, asthma, allergies, BMI, smoking, alcohol use, physical activity, self-rated health, mental health, perceived social support and cognitive Function including alzheimers and dementia.	Sex (male): 1.9 (1.06 - 2.27) **(S)** Age (70-79): 1.89 (1.55 – 2.29) (80 +) 4.58 (3.55 – 5.9) **(S)** Single: 1.43 (1.06-1.91) **(S)** <High School: 1.27 (1.06-1.52) **(S)** Infrequent physical activity: 1.34 (1.12-1.60) **(S)** Underweight: 2.12 (1.44-3.11) **(S)**	7
Fisher et al. (2014)	Prospective Population based cohort Primary + vision and dual sensory	Reykjavik, Iceland N: 4,926 Age: 67-98 Mean age: 76.4 Mean age HL: 78.9	3 - 7 years Median: 5.3 Iceland death registrar	Audiometry Mod/sev: (> 35 dB) in better ear PTA Aggregated none and mild SI for reference	*Age, sex, BMI, hypertension, diabetes, self-rated health, falls history, angina history, cardiovascular history, total cholesterol, hearing aid use, and cognitive Function.*	**All adjustments;** Overall CVD: 1.70 (1.27-2.27) **(S)** Men CVDM: 1.93 (1.3 – 2.87) **(S)** Women CVD: 1.44 (0.93-2.22)	9

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
		M: (n =2,121) F: (n =2,805) UI (n=2,878), HL only (n=1,250) HA use in HL only (n=624) Community dwelling Participation rate: 99.6%		Pure tone air conduction audiometry in sound treated booth.			

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Genther et al. (Jan. 2015)	Prospective population based cohort Primary	Pittsburgh, Pennsylvania & Memphis, Tennessee, USA N= 1,958 Age 70-79 M: (n=936) F: (n=1,022) UI (n=812) HL (n=1,146) HA use (n=250) Urban community dwelling/ Medicare beneficiaries	8 years Death certificate confirmation	Audiometry Any HL: (>25 dB) PTA Pure tone air conduction audiometry in sound treated booth by audiometer “?r and examiner.	*Age, sex, race, education, hypertension, stroke, smoker, diabetes, depression,* gait speed and cognitive function	**Any HL:** Demographic + cardiovascular factors: 1.20 (1.03 – 1.41) **(S)** Full model + depression: 1.20 (1.03 – 1.41) **(S)**	9

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Gopinath et al. (2013)	Retrospective Population based cohort Secondary Dual sensory impairment	Australia N: 2,812 Age: 55+ Mean age DSI: 74 UI: 64 M: (n=1,216) F: (n=1,596) UI: (n=1865) DSI: (n=947) Community dwelling	10 years Australia National Death Index	Audiometry Any HL: (>25 dB) Mild: (>25-40 dB) Mod/severe: (>40 dB) Pure tone air conduction audiometry in sound treated booth	*<u>Age, sex, BMI, systolic blood pressure, smoking, self rated health, walking disability, hypertension, diabetes, hx of cancer, angina, stroke, myocardial infarction, and cognitive function.</u>*	(Table 2 – presenting vision loss) Mild HL: 1.27 (1.01-1.61) (Table 3- best corrected vision loss) mild HL: 1.32 (1.06-1.66) any HL: 1.29 (1.04-1.59)	9
Karpa et al. (2010)	Prospective population based cohort Primary	Australia N: 2,965 Age 50 + Mean age: 66.6 HL mean age: 73 M: (n=1,218) F: (n=1,747) UI: (n=1,886) Mild: (n=635)	8 years Australia National Death Index	Audiometry & Self-Report (56%) UI: (<25dB) Mild: (>25-45dB) Mod/sev: (>45dB) PTA "Do you feel you have hearing loss" Pure tone air and bone conduction audiometry in sound treated booth by audiologist	*<u>Age, sex,</u> smoking, alcohol use, hypertension, BMI, angina, acute myocardial infarction, stroke, cancer, walking disability, self-rated health and cognitive function.*	**Age and sex:** **Mild HL:** CVD: 1.44 (1.04-1.90) **(S)** All Cause: 1.39 (1.09-1.77) **(S)** **Mod/Sev HL:** All Cause: 1.41 (1.06-1.88) **(S)** **SEM** Direct: 1.09 (0.84-1.41) Indirect: 2.37 (1.58-3.54) **(S)**	9

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
		Mod/Sev: (n=294) Community dwelling				Total: 2.58 (1.65-4.05) **(S)**	
Liljas et al. (2016)	Prospective longitudinal cohort Primary	Britain N: 3,981 Age: 63 – 85 Mean age: 72 HL mean age: 73.5 Male only UI: (n=2,907) Not hear/no aid: (n=424) Could hear/used aid: (n=482) Not hear/used aid: (n=168)	10 years National Health Service register	Self-Report Unclear untested instrument No clear definition	*Age, sex, social class, smoking, physical activity, hypertension, diabetes, BMI and cardiovascular disease.*	**Age only:** Could not hear/ No HA 1.19 (1.01 - 1.40) **All adjustments:** Could hear, Used HA: 1.01 (0.86-1.19) Could not hear, No HA: 1.12 (0.93 – 1.34) Could not hear, Used HA: 1.14 (0.89 – 1.45)	6

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Liu et al. (2016)	Retrospective longitudinal cohort Primary + vision, cognition and dual sensory	North Carolina, USA N= 3,871 Age: 65+ M: (n=1,355) F: (n=2,516) UI: (n=2,330) HL: (n=564/ 55.3% female) Community dwelling	6 years National Death Index	Self-Report (a) Have you ever worn a hearing aid? (b) Can you hear and understand a person without seeing his or her face? (c) How often do you wear a hearing aid (1 = *never*, 2 = *occasionally*, 3 = *frequently*, 4 = *always*)? Interviewer: (d) Did respondent have difficulty hearing or was deaf (1 = *no*, 2 = *some*, 3 = *deaf*)? HL was considered present if at least one response indicated HL	Age, sex, race, education, marital status, BMI, history of smoking, depression, and a health index score that reflects self-reported disease burden	**All adjustments:** HL only: 1.11 (0.89-1.39)	7
Lopez et al. (2011)	Retrospective Longitudinal cohort Primary + vision	Australia N: 5,354 Age: 76–81 years. M: (n=2,340) F: (n=3,014)	Mean 6.36 years Australian National Death Index	Self-Report "Do you have difficulty hearing conversation even with HA?"	Age, sex, education, BMI, hypertension, diabetes, stroke, falls, chronic obstructive pulmonary disease, and cardiovascular disease.	**Crude:** Male: 0.95 (0.80-1.13) Female: 1.10 (0.87-1.40) .	6

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
		UI: (n= 4,289) HI: (n= 1,065) Community dwelling					
Schubert et al. (2016)	Retrospective population based cohort Primary + vision and olfactory	Beaver Dam, WI N: 2,418 Age: 53 – 97 Mean age: 69 M: (n=1,021) F: (n=1,397) HL: (n=1,209) UI: (n=1,209) Community dwelling	Mean 12.8 years Maximum of 17 years. Annual contact with participants and local obituaries	Audiometry HI: (>25dB) PTA Every 5 years Pure tone air and bone conduction audiometry in sound treated booth	*Age, sex, education, hypertension, diabetes, CVD, cancer, smoking, BMI, frailty, alcohol use, cognitive function intima media thickness, C reactive protein, and interluken 6*	**Multiple sensory models: Adjusted for everything, but intima media thickness, C reactive protein and interluken 6:** 1.21 (1.01 – 1.45) **(S)** **Full model adjustment:** 1.17 (0.97 – 1.40) .	8

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Wang et al. (2017)	Retrospective longitudinal cohort Secondary VES-13 scale	Taiwan N= 2,184 Age: 65 + M: (n=1,192) F: (n=992) HL: (n= 301) UI: (n= 1,883) Community dwelling	4 years Taiwan Longitudinal Study on Aging (TLSA) database Year: 2003 Survival data collected in 2007 Department of Health death registry	Self-report "Respondents were inquired if they could hear clearly, either with or without hearing aids"	Sex, marital status, education, area of residence, number of chronic diseases, harmful behavior (smoking/drinking), dizziness, depression, incontinence, pain, falls, physical limitations, vision impairment, hearing impairment, low BMI, and cognitive function.	**Multivariate:** 1.323 (1.013 – 1.730) **(S)**	7
Odds Ratio							
Wahl et al. (2013)	Prospective cohort Primary + vision and dual sensory	Two ENT clinics in Heidelberg and Mannheim, Germany N= 430 Age: 75 - 94 M: (n=254) F: (n=176) HL (n=116) UI (n=150)	4 years City registries & family members	Audiometry HI: (>35dB) in better ear PTA 2 years HI prior to enrollment No specification – recruitment through ENT clinic	Sex, age, education, subjective health, living arraignments and activities of daily living.	**Sex only** Any HL; 3.381 (1.444-7.920) **(S)**	9

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
		Community dwelling Participation rate: HI: 96% UI: 97%					
Yamada et al (2011)	Prospective population based cohort Primary	Kurabuchi, Japan N= 1,250 Age: 65+ M: (n=608) F: (n=756) HL male (n= 121) HL Female (n=120) UI: (n=1,123) HA use (n=59/241) Community dwelling Participation rate: 99.4%	3 years Local government	Self-Reported "Do you have difficulty hearing and understanding what a person says to you in a quiet room if they speak normally to you (even with a hearing aid)? No difficulty/a little difficult/ very difficult	*Age, sex, education, social support, marital status, vision, depression and self-rated well being*	**Crude:** Little difficult: 2.20 (1.34 - 3.60) Very difficult: 9.61 (4.06 - 22.75) **All adjustments:** Little difficult: 0.92 (0.52 – 1.64) Very difficult: 2.56 (0.93 – 7.09)	7

Studies	**Design & HL primary or secondary focus**	**Setting, Sample & Participant Rate**	**Length of Follow Up/ Dataset Dates & Outcome Measure**	**Hearing Screening & Definition**	**Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)**	**Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI**	**Newcastle – Ottawa Quality Assessment Scale**
Hospitalization							
Hazard Ratio							
Genther et al. (June 2015)	Prospective population based cohort Primary	Pittsburgh, Pennsylvania & Memphis, Tennessee, USA N= 2,148 Age 70-79 M: (n=1,033) F: (n=1,115) Mild HL (n= 818) Mod/Sev HL (n=448) UI (n=882) HA use (n=196) Urban community dwelling/ Medicare beneficiaries	Median: 12 years Participant self-reported every 6 months	Audiometry Mild: (>25-40dB) Mod/Sev: (>40dB) PTA Pure tone air conduction audiometry in sound treated booth by audiometer and examiner	<u>*Age, sex, race, hypertension, diabetes, stoke, smoking,*</u> <u>CVD</u><u>*, education and income,*</u> cognitive function and hearing aid use.	**Incident hospitalizations:** Mild HL: 1.16 (1.04 – 1.29) **(S)** Mod/Sev HL: 1.21 (1.06-1.38) **(S)** **Annual Hospitalization Rate:** Mild HL: 1.17 (1.04-1.32) **(S)** Mod/Sev HL: 1.19 (1.04-1.38) **(S)**	8

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Odds Ratio							
Chia et al. (2006)	Retrospective cross sectional Primary + vision, cognition and mobility	Australia N = 2,873 Mean age: 66.7 years HL: (n=949) (33.4%) UI: (n=1,551) (54%)	Blue Mountains Eye study Hospitalizations in a 12 month period Self-report	Audiometry Any HL: (>25) Pure tone air conduction	*Age and sex*	**Hospitalizations in 12-month period:** 1.1 (0.9-1.3)	7
Genther et al. (2013)	Retrospective cross sectional Primary	USA N = 1,669 Age 70+ M: (n=848) F: (n=821) Mild HI (n=590) Mod HL: (n=446) sev HI: (n=97) UI (n=529)	NHANES (2005- 2006 & 2009-2010) Hospitalizations in a 12-month period. Computer assisted/ interviewer administered questionnaires – self-report	Audiometry HL: (>25 dB) PTA Database entry of pure tone air conduction audiometry	*Age, sex, race, education level, income, hypertension, diabetes, stroke, CVD, congestive heart failure and smoking.*	**Any Hospitalizations last 12 months:** 1.32 (1.07 – 1.63) **(S)** **Number of Hospitalizations last 12 months:** 1.35 (1.09-1.68) **(S)**	7

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/ Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (underlined/italic confounders adjusted in HR & OR model provided)	Hearing Loss Association to Hospitalization &/or Mortality Adjusted Outcome HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Huddle et al. (2016)	Retrospective cross sectional cohort Primary + vision and dual sensory	USA N=1,669 Age 70+ Mild: (n=436) Mod/sev: (n=413) UI (n=431)	NHANES (2005- 2006 & 2009-2010) Hospitalizations in a 12-month period. Computer assisted/ interviewer administered questionnaires – self-report	Audiometry UI: (<25dB) Mild: (>25-39dB) Mod/Sev: (>40dB) PTA Database entry of pure tone air conduction audiometry	*Age, sex, race, education, income, self-rated health, hypertension, diabetes, stroke, smoking and CVD.*	**Any hospitalizations last 12 months:** Mod/sev: 1.69 (1.14-2.53) **Days of hospitalizations last 12 months:** Mod/sev: 1.78 (1.19-2.65) .	7
Readmission							
Odds Ratio							
Chang et al. (2018)	Retrospective cross sectional Primary	USA N= 4,426 Age: 65+ M: 1,928 F: 2,398 HL M: 251 HL F: 262	Medicare Current Benificiary Survey (MCBS) 2010 – 2013 30 day readmission	Self-Report No trouble communicating / little trouble communicating	*Age, sex, marital status, education, race, ethnicity, income) and health (Elixhauser comorbidities present during index admission self-rated health) factors.*	**Unadjusted:** 1.49 (1.26–1.76) **Adjusted:** 1.32 (1.06–1.64)	6

Key:
BMI: Body Mass Index
CVD: Cardiovascular disease
DSI: Dual Sensory Impairment
F: Female
HA: Hearing aid
HL: Hearing Loss
M: Male
Mod/Sev: Moderate to severe
UI: Unimpaired

Table 3. Newcastle-Ottawa Quality Assessment

	Mortality	Agrawal, 2011	Amieva, 2018	Contrera, 2015	Feeny, 2012	Fisher, 2014	Genther, 2015	Gopinath, 2013	Karpa, 2010	Lilijas, 2016	Liu, 2016	Lopez, 2011	Schubert, 2016	Wahl, 2013	Wang, 2017	Yamada, 2011	Hospitalization	Chia, 2006	Genther, 2015	Genther, 2013	Huddle, 2016	Readmission	Chang, 2018
Selection																							
Representativeness of the exposed cohort		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Selection of the non-exposed cohort		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Ascertainment of the exposure (hearing loss)		*		*		*	*	*	*				*	*				*	*	*	*		
Demonstration that outcome of interest was not present at start of study		*		*		*	*	*	*				*	*				*	*	*	*		
Comparability																							

Comparability of cohorts on the basis of design or analysis (accounts for age/sex* and cognitive function ^)		*	*^	*	*^	*^	*^	*^	*^	*	*^	*	*^	*^	*^	*		*	*^	*	*		*
Outcome																							
Assessment of outcome		*	*	*	*	*	*	*	*	*	*	*		*	*	*							*
Was follow-up long enough for outcomes to occur		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Adequacy of follow up of cohorts		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Total Score		8	7	8	7	9	9	9	9	6	7	6	8	9	7	6		7	8	7	7		6

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CHAPTER 4: HEARING LOSS AND THE ASSOCIATION WITH COMMUNITY HOSPITAL READMISSION IN OLDER ADULTS: A SECONDARY ANALYSIS USING THE NATIONAL READMISSION DATABASE

Introduction

Readmission has been found to have negative effects on health outcomes and financial stability for patients and healthcare organizations. Readmission within 30 days has accounted for 20% of all Medicare discharges (Jencks, Williams, & Coleman, 2009; McIlvennan, Eapen, & Allen, 2015) and it is estimated by the Medicare Payment Advisory Commission that 12% of readmissions are potentially avoidable and that preventing even 10% of these readmissions could save Medicare $1 billion (Jencks et al., 2009; McIlvennan et al., 2015). A systematic review found that a median proportion of avoidable readmissions was at 27% with a range of 5%-79% (van Walraven, Bennett C Fau - Jennings, Jennings A Fau - Austin, Austin Pc Fau - Forster, & Forster, 2011). The relationship between hospital readmission and hearing loss is not well understood, however, patients with hearing loss have double the risk of medication non-adherence compared to their hearing peers (Cardenas-Valladolid et al., 2010), and 10% of all hospital readmission are related to patient non-adherence (Berg, Dischler, Wagner, Raia, & Palmer-Shevlin, 1993; Osterberg & Blaschke, 2005). Furthermore, studies have found those with hearing loss have 33% higher healthcare costs (Simpson, Simpson, & Dubno, 2016), and more annual hospitalizations (Genther et al., 2015) compared to their hearing peers, however, with the exception of two studies, it is not well known if readmissions are the reason for this difference.

Though hearing loss and the association with hospital readmission is not well known, there are common morbidities associated with both variables indicating a need to evaluate this relationship. Common morbidities found to be individually related to hearing loss, increased comorbidities, hospitalizations and readmissions are; diabetes, cardiovascular disorders, falls, lower self-rated health and ADL deficiency (Aliyu, Adediran, & Obisesan, 2003; Dalton et al., 2003; Donovan et al., 2016; Frigola-Capell et al., 2013; Gopinath, McMahon, Burlutsky, & Mitchell, 2016; W. T. Hsu et al., 2016; Hull & Kerschen, 2010; Li, Healy, Drane, & Zhang, 2006; Lin & Ferrucci, 2012; Mener, Betz, Genther, Chen, & Lin, 2013; Oh et al., 2014; Qian & Ren, 2016; Stam et al., 2014; Sung, Li, Blake, Betz, & Lin, 2016). Previous research has established a relationship between hearing loss and multiple comorbidities and those with multiple comorbidities and chronic conditions are more likely to be readmitted to the hospital within 30 days, and have longer and costlier hospitalizations than those without multiple comorbidities (Donze, Lipsitz, Bates, & Schnipper, 2013; Skinner, Coffey, Jones, Heslin, & Moy, 2016). Furthermore, Patients with one or more prior hospitalizations have a higher likelihood of readmission post index hospitalization compared no those with no prior hospitalizations (O'Connor et al., 2016). Moreover, patients whom are admitted via emergency room or transferred to the index hospital were also found to have higher readmission rates (O'Connor et al., 2016). Research also demonstrates that hospital readmission is linked to higher patient morbidity and mortality rates (Wong et al., 2011). Increased readmission rates are found to be correlated to an increase in comorbidities, which has also been found to be an independent indicator of mortality (Oudejans, Mosterd, Zuithoff, & Hoes, 2012).

Negative health outcomes are not the only consequences associated with readmission. Readmission is also linked with increased financial burden, mortality and stress on hospitals, patients and family members (Shams, Ajorlou, & Yang, 2015). In the general population, financial burdens of readmission can occur at the annual cost of 17.4 billion with 17% of this coming from Medicare alone (Shams et al., 2015). One study found that post index hospitalization costs for those with 30-day readmission are substantially higher than those without 30-day readmission. Further, based on these costs in this study, the cost of readmission nationally is estimated to be more than $4.45 billion annually (Chirapongsathorn et al., 2018). This study also found that the highest risk of readmission in their population was increasing age, especially among patients aged 65 and older. Another independent factor associated to readmission found was longer hospitalization with the primary reason for readmission being infection (Chirapongsathorn et al., 2018).

Investigating the relationship between hearing loss and readmission should be made priority as the negative consequences of readmission and hearing loss individually is evident. Further, hearing loss is considered the third most common chronic condition in the elderly affecting over 50 percent of those aged 74 and older (NIDCD, 2016). It is also projected that over 80 million Americans will be over the age of 65 by 2030, thus indicating a possible growth in need for hearing healthcare research and services (Knickman & Snell, 2002). Thus far, only two publications have investigated the association between hearing loss and readmission (Chang, Weinstein, Chodosh, & Blustein, 2018; Reed et al., 2018). Chang et al. found significant associations between hearing loss and readmission resulting in a 32% and 49% higher odds in readmission for patients with hearing loss adjusted and unadjusted, respectively (Chang et al., 2018). Reed et al. another study investigating the association found similar results; patients with hearing loss had 29% increased risk of readmission within 2 years, 28% increased risk over 5 years and 44% increased risk over 10 years (Reed et al., 2018). This study used propensity score matching and found similar results before and after adjustments.

Though these readmission studies provide valuable insight on the association of interest, they did not examine other potential covariates that impact the relationships under study or common primary readmission diagnoses. Further, these studies do not account for patient disposition such as patients discharged standardly, to skilled nursing facilities and to home with home health. It is important to account for patient discharge location as previous research has found significant differences in readmission rates in these populations (Merkow et al., 2015).

Purpose

Health disparities in patients with hearing loss regarding multiple morbidities, hospitalizations and mortality has been relatively well studied, however, the relationship between hearing loss and readmission has not. The purpose of this study is to investigate the relationship between hearing loss and community hospital readmission in older adults.

This study was guided by the following aims regarding hearing loss in older adults:

Aim 1: Compare 30-day hospital readmission for patients with and without hearing loss diagnoses.

> **H1:** Readmission rates will be higher for patients with hearing loss when compared to their hearing counterparts.

Aim 2: Compare length of hospital stay in the index (first) hospitalization for patients with and without hearing loss.

> **H2:** Length of hospital stay in index hospitalization will be longer for patients with hearing loss when compared to their hearing counterparts.

Aim 3: Determine covariates associated with readmission and length of stay in patients with hearing loss.

H3: Patients with hearing loss will have common predicting factors associated to readmission and longer LOS such as older age, Medicare coverage, lower income levels, more chronic comorbidities and OR procedures in index hospitalization.

Aim 4: Investigate most common readmission diagnoses (DX1) for patients with and without hearing loss.

H4: Patients with hearing loss will have common primary readmissions diagnoses pertaining to cardiac disorders, diabetes, cognitive impairment, complications from procedures (i.e. infections), and falls.

Guiding Framework

The guiding framework is a subset of a revised Donabedian framework (Berwick & Fox, 2016). The Donabedian framework is known for assessing the quality of care through a three-step process; structure of care, process of care, and outcomes. In this paper the main focus will be on the following constructs; individual structure (patients), and organizational outcomes (length of hospitalization and readmission) (Figure 2). The mediating construct is process of care which includes unmet healthcare need and self-management. Due to the study design and constraints of secondary analysis using an existing database, we are unable to determine if the process of care had an impact on the relationships among hearing loss, length of stay and readmission. Further research would need to be conducted to assess how much individual structure and characteristics as well as the process of care impact these relationships under study independently. For the remainder of the subsets included in this paper, the individual structure will include patient characteristics such as age, sex, income, insurance type, patient location, sensory deficits, cognitive deficits, cardiac factors, diabetes OR procedures in index hospitalization, and severity of comorbidities via Elixhauser comorbidity index (Elixhauser, Steiner C Fau - Harris, Harris Dr Fau - Coffey, & Coffey, 1998). The structural outcomes will include length of stay and readmissions. This framework will assist with identifying and understanding the relationships among hearing loss, length of hospitalization and 30-day readmission.

Methods

Study design

Using the National Readmission Database (year 2014), a retrospective cohort study was conducted to assess the association between hearing loss status (independent variable) with hospital readmission rates and length of hospitalizations (dependent variables).

Variable definition and measures

The following are the variables with definition of interest in this study. The hearing loss variable was defined by using International Statistical Classification of Diseases codes, also known as, ICD 9 that meet the inclusion criteria. Further explanation of inclusion and exclusion regarding these codes are further in the paper. Readmission rates is defined by patients with a readmission within a 30-day period from the index (first) hospitalization and length of hospital stay is defined by days of stay in the index hospitalization.

Setting

Participants were drawn from the National Readmission Database (NRD) obtained through Healthcare Cost and Utilization Project (HCUP). HCUP which is sponsored by the Agency for Healthcare Research and Quality (AHRQ) and is reprehensive of patients in inpatient settings in hospitals nationwide. The NRD is designed for various analysis of readmission rates nationwide and has a robust sample of 15-35 million discharges every year. The NRD is drawn from and includes 100 percent of the discharges from the State Inpatient Database allowing for us to answer our aims. The State Inpatient Database is under the HCUP database umbrella and is representative of all patient types, payers and uninsured. The NRD database is representative of approximately 50% of the total US population and 50% of all hospitalizations. The exclusion criteria for this database is non-community and rehabilitation hospitals, patients age 0, discharges that have missing or suspect patient identifiers and hospitals with more than 50 percent of their discharges excluded for previous reasons. The sampling frame for the 2014 NRD is limited to discharges for patients treated at community hospitals in the 22 states included that were not rehabilitation or long term acute care facilities. The states include; Arkansas, California, Florida, Georgia, Hawaii, Indiana, Louisiana, Massachusetts, Maryland, Missouri, Nebraska, New Mexico, Nevada, New York, South Carolina, South Dakota, Tennessee, Utah, Virginia, Vermont, Washington, and Wisconsin. The NRD includes variables such as all state inpatient database discharges, patient demographics, diagnosis codes, procedure codes, length of hospitalization and readmission reasons making it an ideal database to utilize for this research question.

Sample

Inclusion: Participants aged 50 and over were included as research supports that older adults recall less information in environments with background noise when compared to their younger peers (Murphy, Craik, Li, & Schneider, 2000). The prevalence of hearing loss has also been shown to increase after the age of 50 (Chia et al., 2007; Ferrite, Mactaggart, Kuper, Oye, & Polack, 2017; Wiley, Chappell, Carmichael, Nondahl, & Cruickshanks, 2008). Further inclusion criteria required that participants; resided in the same state as the hospital, had standard discharge in their index hospitalization, and were admitted non-electively. Patients who had a standard discharge, discharge to long term care facility, or discharged with home health were included. Due to the inability to follow participants across states and years we opted to only include those whom resided in the same state as the hospital and those with discharges in January to November. Participants with elective admissions were not included as previous research has shown significant differences in readmission rates between elective and non-elective admissions (J. G. Berry et al., 2018; Donze, Aujesky D Fau - Williams, Williams D Fau - Schnipper, & Schnipper, 2013). ICD 9 hearing loss diagnoses that were closely associated to age related hearing loss such as; unspecified hearing loss, specified hearing loss, presbycusis, noise induced hearing losses, unspecified sensorineural hearing loss, bilateral sensorineural hearing loss, and bilateral mixed hearing loss were included in our exposure group. For more information on these codes please see **Figure 1.**

Exclusion: Participants were excluded if they died in the hospital, left against medical advice, LOS or NRD_DaysToEvent variable is missing, were discharged in December, or had missing variables included in the propensity score matching (Dorajoo et al., 2017). Participants admitted electively and those with more than 1 readmission in the year were also excluded as those with more than 1 admission tend to have more complex comorbidities and previous research indicates that the more hospitalizations within 6 months to a year can increase readmission risk (Donze, Aujesky D Fau - Williams, et al., 2013). Hearing loss diagnoses that did not closely align with age related hearing loss were excluded. Diagnoses and ICD 9 codes are provided in **Table 1**.

The rationale for the hearing loss diagnoses code exclusion is as follows; patients whom are deaf, especially since birth or childhood, are more than likely aware of their hearing status and more likely to know of resources such as ASL interpreters and the ADA, though they often face challenges obtaining said resources in various settings (Iezzoni, Davis, Soukup, & O'Day, 2003). Therefore, those whom are Deaf will more than likely have differing access to health information compared to those who lose their hearing later in life ultimately making them a different population with unique characteristics and unique challenges. Further, ototoxic hearing loss and sudden idiopathic hearing loss are considered to happen suddenly and is often temporary. Conductive hearing loss could be due to several external factors such as cerumen and could potentially be temporary. Neural hearing loss indicates damage or absence of the auditory nerve and is usually profound and permanent. For this diagnosis, hearing aids are not a viable option as there is no pathway from the ear to the brain to relay sensory information. The remaining excluded ICD 9 codes referred to ear disorders other than the targeted hearing loss for this study. Further, age related hearing loss often occurs bilaterally and symmetrically, therefore any hearing losses that occurred unilaterally or asymmetrically did not meet the inclusion criteria.

Hearing Loss (Exposed). There was a total of 208,881 cases that had 388.x and 389.x ICD 9 codes in variables DX1-DX30 in the year 2014 National Readmission Database. Further details provided in **Tables 1.** We sought patients with hearing loss diagnoses codes closely associated to age related hearing loss to comprise our hearing loss group (exposed group). Further details provided in **Table 2**. Hearing loss diagnoses codes were identified by individual hospitalizations, not subjects. Several subjects (matching NRDVisitLink Indicator ID) had hospitalizations in both the hearing loss (exposed) and no hearing loss (unexposed) groups. It was verified via email by AHRQ that if the hearing loss diagnoses was not coded in every hospitalization for a subject then hospitalizations with no hearing loss diagnoses would subsequently be placed in the no hearing loss (unexposed) group. This indicates that the hospitals or providers did not always code for the hearing loss diagnoses in every hospitalization. We discovered this issue when we were unable to run statistical models as we had subjects in both the hearing loss (exposed) and no hearing loss (unexposed) groups due to inefficient coding of hearing loss. We then transferred the all the hospitalizations without a hearing loss code belonging to subjects with a hearing loss code in other hospitalizations to the hearing loss (exposed) group. This resulted in approximately 20k more cases being added to the hearing loss (exposed) group. The hearing loss ICD 9 code inclusion/exclusion criteria attempted to account for excluding temporary hearing loss such as conductive hearing loss which can be caused by cerumen or solved by procedures. Further, age related hearing loss is often not recognized or identified for 10-15 years by patients as it often occurs bilaterally and symmetrically. Hearing loss is also often unidentified or misdiagnosed by healthcare providers. Therefore the likelihood of someone with a hearing loss diagnoses code not having hearing loss within one year, even if they were not identified, would be minimal.

No Hearing Loss (Unexposed). The unexposed group (no hearing loss diagnoses group) were identified in the NRD 2014 using the same inclusion exclusion criteria applied to the exposed and were further excluded if participants consists of any ICD 9 or procedural codes for hearing disorders/ failed hearing examinations (e.g. 388.x, 389.x, V721.x) in their record.

Matching

The original proposed matching analyses included only propensity score matching (PSM) using the entire dataset. Due to the enormity of the dataset, PSM using the entire dataset was unsuccessful. To run the PSM model we chose to block match then PSM within each block. Variables in the index hospitalization were only used for matching. Index hospitalizations were identified as the lowest value of NRD_DaysToEvent across individual subjects hospitalizations.

Block Matching. Participants were block matched by sex and discharge disposition resulting in a total of six (6) blocks (1) female, standard discharge, (2) male, standard discharge, (3) female, discharge to SNF, (4) male, discharge to SNF, (5) female, discharge with home health, (6) male, discharge with home health. Block matching these variables ensured comparability as participants discharged to a long term care facility were matched with those with the same exact disposition. The same method was used for sex for the same rationale. Previous research has demonstrated associations among patient discharge location, sex, and readmission (Dorajoo et al., 2017; Hughes & Witham, 2018; Silverstein, Qin, Mercer, Fong, & Haydar, 2008; Werner, Coe, Qi, & Konetzka, 2019).

Propensity Score Matching (PSM). Two to one (2:1) greedy nearest neighbor caliper PSM without replacement was applied to each of the 6 blocks to comprise the composite PSM score. 2:1 was chosen due to the high potential risk of predictor contamination in the control group as often times hearing loss is under or misidentified and underdiagnosed (Jalbert M Fau - Primeau & Primeau, 1999; Mahboubi, 2018). To calculate the propensity score, all known variables suspected to be associated to hearing loss and readmission were included. Additional variables that are suspected to significantly affect hospital length of stay were included as well. Participants were matched for age, sex, income, insurance type, patient location, patient discharge disposition, length of stay, Elixhauser comorbidity index, dementia and mild cognitive impairment. Since randomization is not practical due to the study aims, PSM is an attempt to balance the groups under study with respect to measured covariates (Austin, 2011). The rationale for our chosen PSM variables is that when differences in these variables occur, it can impact readmission rates. For example, patients who are; older, have lower income, are covered by Medicare insurance, discharged to long term care facilities, diagnosed with cognitive deficit and have higher Elixhauser comorbidity index scores are more likely to be readmitted than their counterparts (Barnett, Hsu, & McWilliams, 2015; Donze, Aujesky D Fau - Williams, et al., 2013; Garcia-Perez et al., 2011; Herrin et al., 2015; Merkow et al., 2015; Pickens, Naik, Catic, & Kunik, 2017; Ramey et al., 2016; Silverstein et al., 2008). Previous research has also found an association between length of stay and readmission rates (Donze, Aujesky D Fau - Williams, et al., 2013; Garcia-Perez et al., 2011). Previous research also indicates that matching for true confounders is optimal as it results in greater precision of the exposure effect (Austin, Grootendorst, & Anderson, 2007). We opted to include both dementia and mild cognitive impairment ICD 9 codes as previous research demonstrates clinical differences between the two diagnoses and both diagnoses are associated to hearing loss and readmission individually (Knopman & Petersen, 2014). Further, we used ICD 9 codes for dementia used in the Charlson comorbidity index enhanced version and added unspecified dementia as previous research has found that unspecified dementia is the most common code used in healthcare datasets by professionals who are unable to appropriately diagnose dementia specification (Butler, Kowall Nw Fau - Lawler, Lawler E Fau - Michael Gaziano, Michael Gaziano J Fau - Driver, & Driver, 2012; Quan et al., 2005). Variables were chosen a priori and according to the medical literature. Variable names, diagnoses, database codes and ICD 9 codes used are provided in **Table 3.**

Power Analysis

Considering a baseline probability of readmission in the unexposed of 0.15 (Jay G. Berry et al., 2018; Bianco et al., 2012), a probability of readmission in the exposed of 0.30 (Chang et al., 2018; Reed et al., 2018), a conservative covariate correlation of 0.80, a two tailed level of significance of 0.05 and power of 80%, the detectable OR for a difference between the unexposed and exposed with a total estimated sample size of 120,000 (67% in unexposed group, 33% in exposed group) was 1.1.

Analysis Plan Rationale

Readmission. To determine the likelihood of readmission in patients with hearing loss compared to their hearing counterparts was conducted using logistic regression. Odds ratios are the ratio of the probability of an event (readmission) occurring in a group, divided by the probability of that event not occurring (Stare & Maucort-Boulch, 2008). We considered using a count outcome variable in place of a dichotomous outcome variable, however, hospitalizations were heavily right skewed in both groups indicating that there were significantly more subjects with one or two hospitalizations compared to those with 3 or more. This could impact the ability to predict cases with a higher number of readmissions. Additionally, our main objective was to identify if there were differences in readmission risk within 30 days of index hospitalization between the exposed and unexposed groups, not the number of readmissions between groups. Though there are limitations to this method, the decision to not include readmissions after the first readmission (2 hospitalizations total) in our outcome variable improved comparability between groups. Every patient first two hospitalizations were included, and we ignored hospitalizations that followed. Previous research has indicated that previous readmissions within a 6 month to year timeframe can increase risk of subsequent readmissions (Billings, Dixon J Fau - Mijanovich, Mijanovich T Fau - Wennberg, & Wennberg, 2006; Donze, Aujesky D Fau - Williams, et al., 2013).

Length of Stay. Negative binomial regression was used to predict length of stay in the index admission and determine whether hospitalizations were longer in the exposed compared to the unexposed. Due to the over dispersion of the dependent variable, LOS, negative binomial regression proved to be a better fit to the data than Poisson after examination of hanging rootograms for both models and comparison of fit via chi-square tests. The Poisson model is parameterized which indicates that it is best at predicting counts where the mean equals the variance, which was not the case for LOS (Gardner, Mulvey Ep Fau - Shaw, & Shaw, 1995).

Controlled Variables. Previous research has demonstrated that controlling for PSM variables is optimal, even when controlling for other confounders, as it results in less risk of bias in the results (Sjölander & Greenland, 2013). The variables that were adjusted in our two models are; age, sex, income, primary payer, patient location, patient discharge location, index length of stay, Elixhauser comorbidity index score, vision impairment, dementia, mild cognitive impairment, cardiac factors, number of chronic conditions fitting of hearing aid, and OR procedures in index hospitalization. The rationale for the chosen controlled variables is that when differences in these variables occur, it can impact readmission rates and length of hospitalizations. We also wanted to observe the impact of certain variables on the relationships under study. For example, patients who are older, insured by Medicare, discharged to skilled nursing facilities, with lower income levels, sensory deficits, cognitive deficits, cardiac disorders, higher comorbidity index scores, and higher number of chronic conditions were more likely to be readmitted than their counterparts (J. G. Berry et al., 2018; Merkow et al., 2015; Mihailoff, Deb, Lee, & Lynn, 2017). Variables were chosen a priori and according to the medical literature. Variable names, diagnoses, database codes, and ICD 9 codes used are provided in **Table 4.**

Ethical Considerations

Information provided by the National Readmission Database is completely de-identified to protect the privacy of patients, physicians, and hospitals. Additionally, we accessed these data in compliance with the Health Insurance Portability and Accountability Act of 1996. Because this study involved de-identified, publicly available data it was exempted from institutional review board approval by the University of North Carolina at Chapel Hill Institutional Review Board.

Results

Preliminary Groups

After applying the inclusion/exclusion criteria, prior to PSM, the final number of cases for the exposed and unexposed groups were 111,809 and 4,742,197, respectively.

Descriptive Statistics

Prior to Matching. Variables used for matching were compared between groups using chi square and t tests. We compared variables in the index hospitalization only and found statistically significant differences between the groups on most variables. Similar to previous research, the exposed were older, males who tend to be covered by Medicare, with higher percentages of dementia and cognitive impairment, higher Elixhauser scores, and higher discharge rates with home health or to a skilled nursing facility. The exposed also had significantly lower standard discharge percentages compared to the unexposed. Significant differences were also found in income levels, and patient location. The significant differences found in most variables further solidified that PSM was optimal to ensure comparability between groups. Though there was no significant difference between groups in the length of hospitalization, we still opted to match for this to ensure comparability between groups and based on priori research. Further information is provided in **Table 6.**

Post Matching. Adhering to the 2:1 PSM the final number of subjects in exposed and unexposed groups were 81,978 and 163,956, respectively for both readmission and length of stay models. Variables used for matching were compared between groups using t tests. Many variables did not have significant differences such as gender and disposition due to the block matching. Age was also found to have no significant difference between the two groups. Several individual variables did indicate significant differences between the exposed and unexposed groups. Variables included; length of stay, income level, insurance coverage, patient living location, dementia, cognitive impairment and Elixhauser scores. These differences may be explained by the block matching that the PSM score that was created was based on the composite score, not individual covariate scores which can increase the chance of variability, and finally, the sample size of over 200,000 observations allows for substantial power to detect small significant differences. Ultimately, the differences were less than 10% deeming them to be comparable and, therefore, the PSM was deemed successful. Further information is provided in **Tables 7 & 8** for post readmission and LOS model, respectively**.**

Readmission (Aim 1)

The modeling resulted in detecting a statistically significant association with hearing loss and increased odds of 30-day readmission compared to their hearing peers; **(OR, 1.35; 95% CI, 1.32 - 1.38)** and **(OR, 1.29; 95% CI, 1.26 - 1.33),** unadjusted and adjusted, respectively **(Table 9).** All variables and their association to the outcomes under study which were controlled for either through matching or adjustments were also investigated. Models included both groups (combined model) and the hearing loss group only (exposure only model) which resulted in very similar findings. Several variables made the best fitting combined groups model, but did not make the exposure group only model. For example, in the combined model, cognitive impairment and OR procedures were not included in the best fitting model. Furthermore, in the hearing loss only model, variables that did not make the best fitting predictor model were; OR procedures, cognitive impairment, cardiac factors, vision impairment, and age. Further details are provided in **Tables 10 & 11.**

Length of Hospitalization (Aim 2)

Holding model covariates constant, those in the hearing loss group had slightly shorter hospital stays- the length of hospitalization in patients with hearing loss was .**96 (95% CI, 0.95 - 0.96)** times as long of patients without hearing loss (**Table 9**). All variables that were controlled for either through matching or adjustments were also investigated. Models included both groups (combined model) and the hearing loss group only (exposure only model) which resulted in very similar findings. Several other variables made the best fitting combined groups model, but did not make the hearing loss group only model. For example, in the combined groups model all variables that were tested were ultimately included in the best fitting model. However, in the hearing loss only model, one variable that did not make the best fitting model was cognitive impairment. The largest differences between the combined and hearing loss only models in regards to covariates were seen in cognitive impairment and vision impairment. The remainder of the variables, if included in both models, were very similar. While cognitive impairment was not included in the hearing loss only model, vision impairment was and was insignificant in the hearing loss only model compared to the combined model.

Covariates (Aim 3)

Readmission. The predictor models for both combined groups and hearing loss group only were very similar in findings. The largest differences were seen in patient location, income and insurance coverage. The remainder of the variables, if included in both models, were very similar. For patient residence location (PL_NCHS), the odds of readmission amongst both groups decreased significantly the further away from a major metropolitan city in a stepwise fashion. Similarly, patient zip code median income (ZIPINC_QRTL) significantly decreased the odds of 30-day readmission among both groups in a stepwise fashion. Patient insurance (PAY1) was found to be very similar to the hearing loss only model, however, differences were found in those who self-paid and were categorized as "other" compared to the hearing loss only model. Those in the self-paid and other categories were found to have significantly lower odds of 30-day readmission compared to patients covered by Medicare in the combined model. More details regarding the differences between groups in these variables are detailed further in the paper.

There were several covariates that were also found to be significantly associated to readmission risk in patients with hearing loss. These included sex, Elixhauser comorbidity index scores, length of stay, number of chronic conditions, patient location, patient zip code median income, insurance coverage and dementia. Female patients with hearing loss had significantly lower odds of 30-day readmission compared to males with hearing loss **(OR, 0.93; 95% CI, 0.89 - 0.97).** Patients with diagnosed hearing loss and dementia had significantly lower odds of 30-day readmission compared to those with no dementia diagnoses in their index hospitalization; **(OR 0.92; 95% CI, 0.88 - 0.97).** As the Elixhauser comorbidity index score increased 1 point, the odds of 30-day readmission significantly increased **(OR 1.02; 95% CI, 1.02 - 1.02).** Similarly, as the length of stay increased 1 day, the odds of 30-day readmission significantly increased **(OR 1.02; 95% CI, 1.01 - 1.02).** Prior to adjustments, as the number of chronic conditions increased by 1, the odds of 30-day readmissions significantly increased (**OR 1.01; 95% CI, 1.01 - 1.02).** In contrast, after adjustments, as the number of chronic conditions increased by 1, the odds of 30-day readmissions significantly decreased **(OR 0.99; 95% CI, 0.98 - 0.99).**

Patients discharged to skilled nursing facilities, intermediate care and other types of facilities had significantly higher odds of 30-day readmission compared to patients discharged routinely **(OR 1.07; 95% CI, 1.02, 1.13).** Patients discharged with home health services also had significantly higher odds of 30-day readmission compared to patients discharged routinely **(OR 1.16; 95% CI, 1.1 - 1.23).** Patients with hearing loss who lived in metro counties with a population of 50,000 - 250,000, **(OR 0.91; 95% CI, 0.84 - 0.98)**, counties considered micropolitan **(OR, 0.87; 95% CI, 0.8 - 0.95)**, and counties that were considered neither **(OR, 0.84; 95% CI, 0.76 - 0.93)**, had significantly lower odds of 30-day readmission to patients who lived in center counties of metro areas with a population of equal or more than 1 million. Patients who lived in fringe counties of metro areas with a population of equal or more than 1 million did not result in statistically different readmission odds compared to the reference group. Patients who lived in zip codes with a median household income of $51,000 - $65,999 **(OR 0.91; 95% CI, 0.85 - 0.96),** and $66,000+ **(OR 0.91; 95% CI, 0.86 - 0.97)** had significantly lower odds of 30-day readmission risk compared to patients who lived in zip codes with a median household income of $1 - $39,999. Patients with an income level of $40,000 – $50,000 did not result in statistically significant differences **(OR 0.96; 95% CI, 0.91 - 1.02)**. Patients covered by private insurance had significantly lower odds of 30-day readmission compared to those covered by Medicare insurance **(OR 0.89 95% CI, 0.82 - 0.96)**. In contrast, patients covered by Medicaid, self-paid, no charge and categorized as other was not statistically significantly different from those covered by Medicare. Further information is provided in **Table 10 & 11.**

Length of Hospitalization. There were several covariates that were found to be significantly associated to length of hospital stay in patients with hearing loss. Females had hospitalizations .**99 (95% CI, 0.99 – 1.00)** times as long as males. Patients discharged to skilled nursing facilities, intermediate care and other types of facilities had hospitalizations that were **1.73 (95% CI, 1.71 - 1.75)** times as long compared to patients discharged routinely. Patients discharged with home health services had hospitalizations that was **1.36 (95% CI, 1.34 - 1.38)**, times as long compared to patients discharged routinely. Patients with OR procedures had **1.37 (95% CI, 1.35 – 1.39)**, times longer hospitalizations compared to those with no OR procedures. As the Elixhauser comorbidity index score increased 1 point, the incidence of length of hospitalization significantly increased by **1.01 (95% CI, 1.01 - 1.01).** Similarly, as the number of chronic conditions increased by 1, the incidence of length of hospitalization significantly increased by **1.02 (95% CI, 1.01 - 1.02).** As age increased by 1 year, the incidence of length of hospitalization significantly decreased by **0.99 (95% CI, 0.99 – 0.99).**

Patients covered by Medicaid, self-paid and categorized as other had **1.26 (95% CI, 1.22 - 1.30), 1.09 (95% CI, 1.03 - 1.16),** and **1.07 (95% CI, 1.02 - 1.11)** times longer hospitalizations compared to patients covered by Medicare, respectively. There were no statistically significant differences in those covered by private insurance which had **1.01 (95% CI, 0.99 – 1.03)** times the length of hospitalization or had no charge which had **1.02 (95% CI, 0.86 – 1.19)** times the the length of hospitalization. Patients with a dementia diagnoses had **1.06 (95% CI, 1.05 - 1.07)** times longer hospitalization compared to those with no dementia diagnosis. Patients who lived in more rural areas had significantly lower incidence rates compared to those who lived in a major metropolitan city with a population of more than 1 million people. Patients who lived in zip codes with a median household income of $40,000 – $50,999 **0.97 (95% CI, 0.96 - 0.99)**, $51,000 - $65,999 **0.96 (95% CI, 0.94 - 0.97)**, and $66,000+ **0.95 (95% CI, 0.94 - 0.97)** times shorter hospitalizations of those who lived in zip codes with a median household income of less than $39,999. Patients with cardiac diagnoses had **0.98 (95% CI, 0.97 - 0.99)** times the length of hospitalization of those who had no cardiac diagnoses. Further information is provided in **Table 12 & 13.**

Primary Readmission Diagnoses (Aim 4)

Hearing loss (Exposed). For patients with diagnosed hearing loss, the top 20 diagnoses for 30-day readmission in order in descending frequencies are as follows; pneumonia, acute kidney failure, urinary tract infection (UTI), atrial fibrillation, septicemia, ST elevation myocardial infarction (STEMI), chronic obstructive pulmonary disease (COPD) with acute exacerbation, diastolic congestive heart failure (CHF), cerebral infarction, closed fracture of femur neck, systolic CHF, food/vomit pneumonitis, cellulitis of leg, unspecified CHF, closed fracture of femur unspecified, coronary atherosclerosis, hyponatremia, syncope and collapse, cerebral ischemia; unspecified and acute respiratory failure. See **Table X** for further details.

No Hearing Loss (Unexposed). For patients with diagnosed hearing loss, the top 20 diagnoses for 30-day readmission in order in descending frequencies are as follows; septicemia, pneumonia, acute kidney failure, COPD with acute exacerbation, atrial fibrillation, STEMI, urinary tract infection, systolic CHF, cerebral infarction, diastolic CHF, coronary atherosclerosis, cellulitis of leg, unspecified CHF, acute respiratory failure, acute pancreatitis, respiratory failure, diverticulosis of colon, gastrointestinal hemorrhage, food/vomit pneumonitis, and intestinal obstruction unspecified. See **Table 14** for further details.

Discussion

In a 2:1 matched cohort study of up to 245,934 observations using the National Readmission database, hearing loss diagnosis was associated with higher odds of 30-day readmission and slightly shorter hospital stays. Several variables were found to be associated with increased odds of readmission and shorter length of hospital stay. These variables included

Elixhauser comorbidity index scores, length of stay (for readmission model only), age (LOS model only), cardiac factors (LOS model only), patient disposition, number of chronic conditions, sex, patient location, income, dementia diagnoses. and insurance coverage.

Descriptive Statistics

Prior to PSM. The preliminary descriptive resulting in statistically significant differences between our two groups in nearly all variables were not surprising as previous research indicates this is a relatively expected finding. One variable that was somewhat surprising was the income levels as the exposed had income levels that had ascending percentages indicating that higher percentages of the exposed had higher income levels compared to lower income levels. Furthermore, the unexposed showed an opposite effect with descending percentages indicating that higher percentages of the unexposed had lower income levels compared to higher income levels. The preliminary findings indicating that the exposed had higher income level percentages compared to the unexposed could indicate that those with higher income levels are more likely to have improved access to healthcare and subsequently potentially more likely to be diagnosed with hearing loss. This would not be surprising as previous research has demonstrated a significant relationship between income inequality and healthcare inequality (Dickman, Himmelstein, & Woolhandler, 2017).

Readmission & Length of Hospitalization (Aim 1 & 2)

A matched 2:1 cohort, patients with diagnosed hearing loss had significantly higher odds of 30-day readmission compared to their hearing peers. Unadjusted, patients with a hearing loss diagnoses had 1.35 higher odds of 30-day readmission compared to hearing peers. Adjusted resulted in 1.29 higher odds of 30-day readmission indicating that effect of hearing loss diagnoses on 30-day readmission is significant even with comparable groups. The 6% decrease in odds of 30-day readmission after adjustments can be due to several factors. First, we adjusted for all matched variables as well as other variables that were deemed important based on priori research. Variables that were not matched, but were adjusted, such as number of chronic conditions, cardiac factors and vision impairment could have attenuated the relationship between hearing loss and 30-day readmission. Secondly, matching was based on block matching as well as a composite propensity score which means the diagnostics of how heavily covariates weighed in the PSM are not available

Our readmission findings are very similar to Chang et al. and Reed et al. which investigated the association between hearing loss and 30-day readmission (Chang et al., 2018; Reed et al., 2018). Chang et al. found significant associations with hearing loss and readmission resulting in a 32% and 49% higher odds in readmission for patients with hearing loss adjusted and unadjusted, respectively (Chang et al., 2018). Reed et al. found patients with hearing loss had 29% increased risk of readmission within 2 years, 28% increased risk over 5 years and 44% increased risk over 10 years (Reed et al., 2018). Reed et al. used propensity score matching and found similar results before and after adjustments. Chang et al. did adjust for several important covariates, however they may have higher odds of readmission for the exposed group due to the fact that they did not use matching methods, or account for cognitive impairment or mobility which could bias results. Reed et al. results were very similar to our study. Reed et al. was conducted over time, blocked matched by 2, 5 and 10 years to investigate the associations. Reed et al. did not have a large increase in readmission risk from 2 years to 5 years, however, they did see significant increase from 5 years to 10 years. Our study used 1 year in the National Readmission Database and we only used the first 2 hospitalizations within that year to decrease bias from previous hospitalizations and improve comparability among groups. With our study closely matching Reed et al. 2 year and 5 year results, this suggests that hearing loss may have a significant effect on 30-day readmission fairly quickly at a certain level and remain at that level for several years. Hearing loss often worsens with age and time, and previous research has found that moderate to severe hearing loss has stronger associations with negative health outcomes such as mortality and hospitalizations compared to mild and no hearing loss (Contrera, Betz, Genther, & Lin, 2015; Feeny et al., 2012; Fisher et al., 2014; Genther, Betz, Pratt, Kritchevsky, et al., 2015; Huddle, Deal, Swenor, Genther, & Lin, 2016; Wahl et al., 2013; Yamada, Nishiwaki, Michikawa, & Takebayashi, 2011). This could potentially explain why the odds of 30-day readmission were much higher over a 10-year period.

There are a few potential reasons why patients with a hearing loss diagnoses have higher odds of 30- day readmission and slightly shorter hospitalizations in our study. First, patients with hearing loss are at risk for being less engaged by healthcare providers due to the combination of patients' difficulty hearing, provider perceived time constraints, and the providers lack of knowledge regarding the available accommodations or consequences of unaddressed hearing loss (Arlinger, 2003). This may motivate providers to take a paternalistic approach when communicating with hard of hearing patients, unintentionally excluding patients from their plan of care. For example, in (Boltz, Parke, Shuluk, Capezuti, & Galvin, 2013), nurses expressed concern for patient autonomy and control of their own health care, as providers often talk with family members about important medical decisions and may neglect to include the competent patient (Arlinger, 2003; Boltz et al., 2013). Another study investigated the association between hearing loss and patient activation (patient knowledge, skill and confidence to participate actively in their healthcare) and found that the relationship was statistically significant (Chang, Weinstein, Chodosh, Greene, & Blustein, 2019). Chang et al. also found that the risk varied by hearing severity. For example, patients with little trouble hearing were 1.42 times more likely to have low vs high patient activation. Patients with a lot of difficulty hearing were 1.70 times more likely to have low vs high patient activation compared to their hearing peers (Chang et al., 2019). This indicates that as hearing loss severity worsened there was a higher risk for low vs high patient activation. Previous research has also found associations among hearing loss, low health literacy and higher odds of readmission (Baker et al., 2002; Berkman, Sheridan Sl Fau - Donahue, Donahue Ke Fau - Halpern, Halpern Dj Fau - Crotty, & Crotty, 2011; Safeer & Keenan, 2005). These factors could potentially result in premature discharge of these patients subsequently resulting in higher odds of 30-day readmission. Moreover, as seen, the exposed group having higher odds of 30-day readmission and slightly shorter hospitalization, and previous research has demonstrated that shorter hospitalizations can result in higher odds of readmissions (Horney, Capp, Boxer, & Burke, 2017). In contrast, length of hospitalization in the index stay had significant associations with 30-day readmission in the exposed. Though the effect was small, for every 1 day increase of hospital stay, the odds of 30-day readmission increased by 1.02. Further research investigating the relationship between hearing loss and length of hospitalization is needed as few studies have looked at this association.

Covariates (Aim 3)

Several covariates were significantly associated to 30-day readmission and length of stay in the exposure group. The covariate with the largest effect on the relationships under study was patient discharge destination. Patients discharged to skilled nursing facilities and with home health had 1.07 and 1.16 significantly higher odds of 30-day readmission compared to those discharged routinely after adjustments, respectively. In line with previous research, patients discharged with home health had higher odds readmission compared to those discharged to skilled nursing facilities (Werner et al., 2019) and those discharged to either had higher odds of readmission compared to those discharged routinely (Dorajoo et al., 2017). Patient discharge destination was also significantly associated with length of hospitalizations in the exposed group. After adjustments, patients discharged to skilled nursing facilities had 1.73 times longer hospitalizations compared to those discharged routinely. Patients discharged with home health services had 1.36 times longer hospitalizations compared to those discharged routinely. Previous research has demonstrated significant associations among discharge locations and hospital readmissions and length of stay (Silverstein et al., 2008; Werner et al., 2019). The purpose of home health is to provide healthcare services at a lower cost and convenience to patients at their home. Though home health is aimed to improve patients' healthcare including, but not limited to adherence to medication regiments and understanding of disease processes to potentially decrease readmission risk, home health can also result in healthcare professionals identifying health issues more quickly subsequently increasing 30- day readmission risk compared to patients routinely discharged. For length of stay, several reasons for significantly higher incidence of longer hospitalizations could be due to the fact that patients whom are discharged to skilled nursing facilities and with home health tend to be sicker than those routinely discharged potentially requiring more specialized care.

Several other covariates presented similar results in both models. For example, patients who lived in zip codes with a higher average median household incomes had significantly lower odds of 30-day readmission and shorter hospitalizations compared to those who lived in zip codes with lower average median incomes. This was not surprising as previous research has established relationships among income, readmission and length of stay as income level and healthcare utilization has been well studied (Hu J Fau - Gonsahn, Gonsahn Md Fau - Nerenz, &

Nerenz, 2014; Kangovi et al., 2014; Kind Aj Fau - Jencks et al., 2014). Patient location was also significantly associated with readmission and length of hospitalization. In both models, the further away patients lived from metropolitan counties with population of more than 1 million, the lower the odds were for readmission and the lower the incidence for longer hospitalizations. This was was interesting as previous research has suggested that patients whom live in rural, less populated areas tend to be older, considered a minority, and less healthy due to socioeconomic status, as well as access to nutritious food and healthcare services (Nayar, Yu F Fau - Apenteng, & Apenteng, 2013; Tjaden, 2015). Though it was hypothesized that patients with hearing loss living in rural areas would have higher odds of 30-day readmission due to limited access to follow-up appointments, pharmacies, primary care providers, and healthy foods, it does make sense how it could be the opposite. Populations in rural areas tend to be older and more socially and economically disadvantaged compared to populations living in urban areas (Tjaden, 2015). This could limit access to necessary healthcare in a timely fashion (readmission within 30 days vs. after 30 days) due either proximity to healthcare facilities or proper knowledge of health status.

Patient insurance coverage type was also significantly associated with readmission and length of hospitalization. Patients covered by private insurance and self-paid had significantly lower odds of 30-day readmission compared to those covered by Medicare. For length of hospitalization, patients covered by Medicaid, self-paid or were categorized as other had significantly higher incidence of longer hospitalizations compared to patients covered by Medicare. These findings were not surprising as Medicare covers older adults aged 65 and older whom are often older, sicker, and require more specialized care compared to those who are younger and covered by private insurance (J. G. Berry et al., 2018). Medicare coverage has been associated to higher risk of readmission in previous studies (J. G. Berry et al., 2018; Strom et al., 2017). Furthermore, patients with private insurance or self-paid are more likely to have higher income subsequently potentially reducing readmission risk due to other protective factors (Hoerl et al., 2017).

Females in both models had significantly lower odds of 30-day readmission and shorter length of hospitalizations compared to males. This is in line with previous studies which have indicated that that males often have higher risk of readmission (J. G. Berry et al., 2018; Hu J Fau - Gonsahn et al., 2014; Hughes & Witham, 2018). The Elixhauser comorbidity index scores were also significant for higher odds of readmission and incidence of longer hospitalizations. Though the effect was small, the prediction was optimal as confidence intervals were extremely close indicating with high certainty that as the Elixhauser comorbidity score increased by 1 point, the odds of 30-day readmission increased by 2%. Similarly, with length of hospital stay model, as the Elixhauser comorbidity score increased by 1 point, the incidence of longer hospitalizations increased by 1%. Length of stay was also significantly associated with readmission as the length of stay increased by 1 day, the odds of 30 – day readmission increased by 2%. These findings are similar to previous research which has found associations among comorbidity index scores, readmission risk and longer hospitalization (Dias et al., 2015; Lakomkin et al., 2017). The number of chronic conditions was also significant in both models. As the number of chronic conditions increased by 1, the odds of readmission and incidence of longer hospitalizations significantly increased by 1% and 2%, respectively. This finding was expected as previous research has demonstrated associations among more chronic conditions, higher readmission risk and longer hospitalizations (Mihailoff et al., 2017). Though the effect can be perceived as small among the Elixhauser comorbidity index, length of stay, and number of chronic conditions, it is important to remember that as a continuous variable, comorbidity index scores and hospital stay days can accumulate subsequently increasing the risk of readmission and longer hospitalizations more than initially seen in these results.

Primary Readmission Diagnoses (Aim 4)

The readmission diagnoses with the highest frequencies shared many similarities among both groups. For example, as hypothesized, diagnoses closely associated with infections and cardiac disorders were commonly seen in the top 20 30-day readmission diagnoses. Commonly seen infections in both groups were; septicemia, pneumonia, UTI, food/vomit pneumonitis, and cellulitis of the leg. Commonly seen cardiac related diagnoses in both groups were; systolic, diastolic and unspecified CHF, coronary atherosclerosis, STEMI, and atrial fibrillation. COPD, cerebral infarction, acute kidney failure, and acute respiratory failure were also found in both groups. There were also differences between the two groups. For example, in the unexposed group, diagnoses associated to gastrointestinal disorders were present such as; diverticulosis of colon, GI hemorrhage, and unspecified intestinal obstruction. In contrast, the exposed group had diagnoses commonly related to falls rather than gastrointestinal disorders. For example, the exposed group had three diagnoses associated with falls; closed fracture of femur neck, unspecified closed fracture of femur and syncope and collapse that made the top 20 diagnoses. Closed fracture of the femur neck even made number 10 with 1.74% of the exposed primary readmission diagnoses.

Diagnoses associated to cardiac disorders and infections found in the top 20 of both groups was not surprising as previous research has demonstrated associations among several of these diagnoses and readmission risk (Goldberg, Morphis, Youssef, & Gardner, 2017; Hughes & Witham, 2018; Unruh, Trivedi An Fau - Grabowski, Grabowski Dc Fau - Mor, & Mor, 2013).

Other diagnoses commonly found in both groups such as COPD, cerebral infarction, acute kidney failure and acute respiratory failure have also been found to have associations with readmission in previous research (Koekkoek, Bayley Kb Fau - Brown, Brown A Fau - Rustvold, & Rustvold, 2011; Prescott, Sjoding, & Iwashyna, 2014). As hypothesized, patients with diagnosed hearing loss had diagnoses commonly seen in falls in older adults in the top 20 primary readmission diagnoses. These diagnoses included closed fracture of the femur neck, unspecified close fracture of the femur, and syncope and collapse. In contrast, the unexposed group did not have any of these diagnoses in the top 20. Upon further inspection, the unexposed group had 2 of the 3 diagnoses in the top 30 primary diagnoses (closed fracture of femur neck, syncope and collapse). This finding is not surprising as previous research has demonstrated a significant association between hearing loss and falls (Jiam, Li, & Agrawal, 2016).

Hearing loss and its association with falls could be due to multiple factors. Biological factors such as the aging process impacting the cochlear and vestibular systems potentially impacting balance could increase fall risk (Seidman, Quirk Ws Fau - Shirwany, & Shirwany, 1999; Shiga et al., 2005). Previous research has demonstrated a relationship amongst hearing loss was aging and sex (A. K. Hsu et al., 2019). Hearing loss was commonly seen in older white males, and Caucasians are especially at risk for osteoporosis increasing potential risk of falls (Cauley, 2011). Due to the inability to identify race for this study, our groups may not be comparable with regards to race thus creating unintended bias. Environmental factors can also impact the association with falls. For example, background noise is considered to be a major functional impediment to individuals with hearing loss. Hearing loss often results in reduced speech recognition ability and when compared to younger peers older adults recall les information that is provided to them in environments with high background noise (Murphy et al., 2000). Perception between older adults and younger adults also greatly vary in similar environments with high background noise. Older adults with hearing loss tend to perceive the noise levels and interference with spoken language as higher compared to their hearing peers (Kramer, Kapteyn, & Houtgast, 2006; Murphy et al., 2000). Environments with high background noise coupled with common perception of noise levels and interference of older adults with hearing loss can result in more *cognitive workload* (defined as the effort required to ignore background noise and to consolidate important information in short-term memory while discarding what is not important to understand or remember) on the patient (Kramer et al., 2006; Murphy et al., 2000; Pichora-Fuller & Singh, 2006). This cognitive workload can then potentially result in less attention being paid to surroundings causing falls (Jiam et al., 2016; Rumalla, Karim Am Fau - Hullar, & Hullar, 2015). Another consideration is the patients potential limited access to pertinent health information regarding medication regimens and post operation ambulation which could have assisted with preventing falls.

Future Implications

Future research should consider investigating the relationships among hearing loss, readmission, and length of hospitalization in a prospective longitudinal design using audiometry and accurately measure and account for common confounders to better understand the relationships. Mixed methods should also be considered to ensure inclusion of qualitative data such as experiences of hard of hearing patients as well as healthcare staff whom work with them. It is not well known where the breakdown occurs in patients with hearing loss such as whether it is due to potential health issues from social isolation, lack of hearing loss identification and diagnoses, or lack of accommodations in healthcare settings leading to miscommunication, low patient activation or unintentional non adherence. Previous research has demonstrated how hearing loss severity impacts the association with negative health outcomes. Therefore, future research should consider investigating the association between hearing loss severity and readmission. Furthermore, considering the large amount of the exposed initially missed due to the lack of hearing loss codes in every hospitalization in this data, special attention should be paid to when these hearing loss codes occur and how it was measured in studies that pan over several years.

Three studies available in the literature, including this one, have supported an increase in odds of 30-day readmission of at least 29% in patients with hearing loss compared to their hearing peers (Chang et al., 2018; Reed et al., 2018). Several previous studies investigating hearing loss and the association with negative health outcomes such as various comorbidities, hospitalizations, and mortality have also demonstrated significant associations (A. K. Hsu et al., 2019). Studies investigating hearing accommodation use, within the general population and healthcare settings, have demonstrated positive outcomes (A. K. Hsu et al., 2019; Kimball et al., 2017; Mahmoudi, Zazove, Meade, & McKee, 2018). With this growing body of research in hearing healthcare, policy makers should consider making hearing accommodation use and hearing screening in healthcare settings a priority to assist with improving healthcare experiences and outcomes in these patients.

Limitations

Several limitations in this study should be considered. First, this was a secondary analysis utilizing a dataset that is not created specifically for our research aims therefore accurately measuring for hearing loss and accounting for common confounders was not always possible. The data collected in the National Readmission Database was extracted from the State Inpatient database which is mainly for hospital use. Second, when the exclusion criteria were applied some readmissions may have not been captured so we may have underestimated the readmission rate. The same issue occurred in both hearing loss and non-hearing loss groups. Third, hearing loss is often not appropriately recognized or diagnosed, especially in health care settings where acute health conditions are priority. This is demonstrated in our preliminary findings of the diagnosis of hearing loss often not being coded in every hospitalization, even for the same subjects with the hearing loss code elsewhere suggests high chance of predictor contamination in the control group. This suggests that hearing loss may be missed during hospitalizations, or that is is not appropriately coded into the database. Hearing loss can often be confused with dementia or delirium, as patients with hearing loss can respond inappropriately and thus may be misdiagnosed (Gower, Gatewood, & Kang, 2012). There is also a potential limitation of misclassification bias for hearing loss as well as dementia and mild cognitive impairment. Similar to hearing loss not being coded in every hospitalization, patients with dementia or mild cognitive impairment diagnoses in hospitalizations other than their index hospitalization could have been misclassified in our analyses. We will also not know the severity of hearing loss as this is not available through ICD codes in the database. Research has also demonstrated that the more severe the loss of hearing, the higher the likelihood for negative health outcomes (Genther, Betz, Pratt, Martin, et al., 2015; Huddle et al., 2016; Yamada et al., 2011). Further, it is impossible to tell who is screening and coding the patient (e.g. physician vs. audiologist), and how hearing loss is measured whether it is subjectively or objectively (e.g. self-report vs. audiometry). Similar to hearing loss, cognitive impairments such as dementia are often underdiagnosed and not coded in healthcare databases (Wilkinson et al., 2018). This increases the likelihood of PSM patients with no cognitive impairment diagnoses and one actually having undiagnosed cognitive impairment potentially resulting in less comparable groups.

One weakness with PSM is though PSM attempts to balance groups under study with respect to measured covariates, this does not account for unmeasured covariates. Additionally, patient linkage (NRD_VisitLink) is derived from the state inpatient database which cannot be followed through years or between states and thus can result in missed readmissions. The strong limitation of only using 1 year should also be considered as previous research which investigated hearing loss and readmission found that the differences in risk for readmission increased significantly between groups as the length of time increased (Reed et al., 2018). Though we were able to match for several variables that were considered important, even those variables had limitations within themselves. For example, though the ZIPINC_QRTL variable which is the median household income quartiles for patients' zip code sheds some light on how income impacts the relationships under study and assists with ensuring comparability between groups, it is not as accurate as other methods for obtaining patient income such as geocoding or individual income.

We were also unable to account for race, mobility, self-rated health, health literacy, and whether patients went home alone or with family at standard discharge as this data was not available. Previous studies have found associations among race, mobility, self-rated health and health literacy to negative health outcomes in patients with hearing loss suggesting the importance of including these variables in future studies (Berkman et al., 2011; A. K. Hsu et al., 2019). Variables that we considered but could not use are; history of Falls (V15.88) as definition is not clear of when falls occurred and the number of falls, and disability examination (V68.01) as there is no way to assess outcome of examination using this variable. Other codes for hearing loss that were considered but not used are; (V41.2) problems with hearing, as we cannot decipher the exact problem and if it is temporary or permanent. Hearing exam fail screen (V72.11) was also considered but could not be used as we are unable to determine why they failed and if it was due to outside factors such as screening or cerumen buildup.

Lessons Learned

Several lessons were learned during the implementation of this secondary data analysis. First, as expected, hearing loss was rarely diagnosed and even if it was, it was not coded in every hospitalization for all subjects. Surprisingly, hospitalizations with any 388.x and 389.x codes only accounted for 208k out of approximately 35 million discharges derived from the state inpatient database. As aforementioned, hearing loss is often not recognized for 10-15 years and often worsens with age and time. Additionally, moderate to severe hearing loss if often more recognizable by patients, family and friends due to the increased limitations caused by the disability. Therefore, patients with diagnosed hearing loss in our dataset may be more likely to have moderate to severe hearing losses compared to mild hearing loss. These factors indicate a likelihood of misclassification bias resulting in possible predictor contamination in the unexposed/reference group. This also emphasizes the importance of investigating optimal hearing screening methods as well as audiology referrals in various healthcare settings to potentially improve hearing loss identification and subsequently diagnoses.

Another lesson learned is the application of exclusion criteria on this type of dataset. Because our samples were identified using cases, not subjects, this may have resulted in readmissions not being captured unintentionally and subsequently resulted in an underestimated readmission rate. This same issue occurred in both the hearing loss (exposed) and no hearing loss (unexposed) groups. Though this database provides insight on this phenomenon, one major limitation is the possibility of miscoding of not only hearing loss but also other diagnoses such as dementia, mild cognitive impairment and ICD 9 codes associated to the Elixhauser comorbidity index score and our covariates. Index hospitalizations were only used to identify these variables therefore misclassification regarding all variables may have occurred. The suggestion is that in future studies, while using this database, non-index hospitalization diagnoses codes should be considered and compared. Due to the nature of being able to follow patients for a maximum of 1 year, it is not recommended that this database be used for readmissions longer than within a 90-day period as this can result in several missed admissions. Unfortunately, we were unable to detect if index hospitalizations in January 2014 were a readmission from a December 2013 hospitalization due to this limitation which could have skewed our results and potentially increase bias.

Conclusion

Hearing loss diagnoses was significantly associated to higher odds of 30-day readmission and lower incidence for hospitalizations compared to a 2:1 matched cohort of those with no hearing loss diagnosis. Even with block and propensity score matching and after adjusting for known confounders such as patient discharge location, sex, age, income, insurance, patient location, Elixhauser comorbidity index scores and various comorbidities, patients with diagnosed hearing loss still had significantly higher odds of readmission. Though several limitations are to be noted and matching does not account for unmeasured covariates, this study indicates that hearing loss has significant effect on readmission and length of stay independent of the accounted covariates. Common covariates associated with higher odds of 30-day readmission in the exposed were male sex, no dementia diagnoses, higher Elixhauser comorbidity index scores, longer hospitalizations, discharge to skilled nursing facilities or with home health, living in more populated areas, lower income, and covered by Medicare insurance. Common covariates associated to longer length of hospitalizations in the exposed were male sex, no cardiac diagnoses (of which we accounted for), OR procedures in index hospitalization, higher number of chronic conditions, higher Elixhauser comorbidity index scores, dementia diagnoses, living in more populated areas, lower income, and covered by Medicaid, self-pay and categorized as other. Future research should consider investigating this phenomenon in a prospective longitudinal design using audiometry and accurately measure and account for common confounders to better understand the relationship under study. It is well not known where the breakdown occurs in patients with hearing loss such as whether it is due to potential health issues from social isolation, lack of hearing loss identification and diagnoses, or lack of accommodations in healthcare settings leading to miscommunication, low patient activation or unintentional non adherence.

Table 1. 388 – 389 ICD 9 Codes

Diagnosis	ICD 9 Code	Count	Percentages
Sudden hearing loss	388.2	83	**<1%**
Disorders of the acoustic nerve	388.5	280	**<1%**
Other disorders of the ear	388.8	523	**<1%**
Unspecified disorder of ear	388.9	248	**<1%**
Deaf non-speaking	389.7	3,720	**2%**
Specified hearing loss	389.8	3,449	**2%**
Unspecified hearing loss	389.9	157,948	**76%**
Degenerative vascular disorder of the ear	388.00	2	**<1%**
Presbycusis	388.01	2,551	**1%**
Trans ischemic deafness	388.02	8	**<1%**
Noise induced hearing loss unspecified	388.10	5	**<1%**
Acoustic trauma	388.11	12	**<1%**
Noise induced hearing loss	388.12	53	**<1%**
Tinnitus unspecified	388.30	10,731	**5%**
Tinnitus subjective	388.31	130	**<1%**
Tinnitus objective	388.32	110	**<1%**
Abnormal auditory perception	388.40	211	**<1%**

Diplacusis	388.41	2	**<1%**
Hyperacusis	388.42	121	**<1%**
Impairment of auditory discrimination	388.43	18	**<1%**
Auditory recruitment	388.44	1	**<1%**
Acquired auditory processing disorder	388.45	91	**<1%**
Otorrhea unspecified	388.60	622	**<1%**
Otorrhea CSP	388.61	638	**<1%**
Otorrhea other	388.69	936	**<1%**
Otalgia	388.70	5,074	**2%**
Otogenic pain	388.71	104	**<1%**
Otogenic pain; referred	388.72	64	**<1%**
Conductive hearing loss; unspecified	389.00	1,330	**1%**
Conductive hearing loss; external ear	389.01	9	**<1%**
Conductive hearing loss; tympanic membrane	389.02	27	**<1%**
Conductive hearing loss; middle ear	389.03	73	**<1%**
Conductive hearing loss; inner ear	389.04	8	**<1%**
Conductive hearing loss; unilateral	389.05	415	**<1%**
Conductive hearing loss; bilateral	389.06	343	**<1%**

Conductive hearing loss; combined	389.08	17	**<1%**
Sensorineural hearing loss; unspecified	389.10	8,691	**4%**
Sensorineural hearing loss; bilateral	389.11	847	**<1%**
Neural hearing loss; bilateral	389.12	235	**<1%**
Neural hearing loss; unilateral	389.13	166	**<1%**
Central hearing loss	389.14	144	**<1%**
Sensorineural hearing loss; unilateral	389.15	1,073	**1%**
Sensorineural hearing loss; asymmetrical	389.16	890	**<1%**
Sensorineural hearing loss; unilateral	389.17	463	**<1%**
Sensorineural hearing loss; bilateral	389.18	4,565	**2%**
Mixed hearing loss; unspecified	389.20	855	**<1%**
Mixed hearing loss; unilateral	389.21	377	**<1%**
Mixed hearing loss; bilateral	389.22	618	**<1%**
	Total	208,881	100%

a. **This table may not add to 100% as all codes were rounded to the nearest whole percent**

b. **Bold diagnoses are included in study**

Table 2. 388 – 389 Included ICD 9 Codes Prior to PSM

Diagnosis	ICD 9 Code	Count	Percentages	Cumulative Percentages
Unspecified hearing loss	3899	84,656	88	88
Specified hearing loss	3898	1,408	1	89
Presbycusis	38801	1,707	2	91
Noise induced hearing losses	38812	12	<1	91.5
Unspecified sensorineural hearing loss	38910	4,594	5	96.5
Bilateral sensorineural hearing loss	38911, 38918	2,649	3	99.5
Bilateral mixed hearing loss	38920, 38922	701	<1	100
	Total	95,727		

Table 3. Matched Variables Key

Variable	Database Codes Used
Block Matching	
Sex (FEMALE)	0 – Male (reference) 1 – Female
Patient Disposition (DISPUNIFORM)	1 – Routine (reference) 5 - Other transfers, including skilled nursing facility, intermediate care, and another type of facility 6 - Home health care
Propensity Score Matching	
Age (AGE)	50-90 years, anyone > 90 = 90
Expected Primary Payer (PAY1)	1 – Medicare (reference) 2 – Medicaid 3 – Private Insurance 4 – Self-pay 5 – No charge 6 - Other
Patient Location (PL_NCHS)	1 - "Central" counties of metro areas of >=1 million population, (reference) 2 - "Fringe" counties of metro areas of >=1 million population, 3 - Counties in metro areas of 250,000- 999,999 population 4 - Counties in metro areas of 50,000-249,999 population, 5 - Micropolitan counties 6- Not metropolitan or micropolitan counties
Zip Code Median Household Income (ZIPINC_QRTL)	1 - 1 - 39,999 (reference) 2 - 40,000 - 50,999 3 - 51,000 - 65,999

	4 - 66,000+
Length of Stay (LOS)	Count
	ICD 9 Codes
Dementia (Deyo - Enhanced Version)	290.x, 294.1, 331.2
Dementia; Unspecified	294.2
Mild Cognitive Impairment	331.83
Elixhauser Comorbidity Index; AHRQ Version	

Table 4. Covariates for Adjustment Key

Variable/ Diagnoses	Database (D) and ICD 9 (Dx)
Major Operating Room Procedures in Index Hospitalization (D) (ORPROC)	1 – Surgery 0 – No surgery
Number of Chronic Conditions (D) (NCHRONIC)	Count
Vision Impairment (Dx)	369.x
CVD; Unspecified (Dx)	429.2
Heart Disease; Unspecified (Dx)	429.9
Hypertension; Uncomplicated (Deyo – Enhanced Version) (Dx)	401.1, 401.9, 642.0
Hypertension; Complicated (Deyo – Enhanced Version) (Dx)	401.0, 402.x-405.x, 642.1, 642.2, 642.7, 642.9
Atherosclerosis (Dx)	440.x

Table 5. Hearing Loss (Exposed) and No Hearing Loss (Unexposed) prior to PSM Sample

Sample size		Exposed (1)	Unexposed (0)	Total
Index and 1st readm only		113476	4828746	4942222
	index	83181	3842568	
	readm	30295	986178	
Missing Removed		111809	4742197	4854006
	index	81979	3775454	
	readm	29830	966743	996573
	readm 30 days	11688	396030	
Less removed as elixhauser could not be calculated		111808	4741335	4853143
	index	81978	3774592	3856570
	readm 30 days	11688	395930	

Table 6. Descriptive Statistics on Index Hospitalization for Hearing loss (1) and No Hearing Loss (0) (Pre PSM)

	Stratified by group 0	1	p	test	SMD
n	3774592	81978			
AGE (mean (sd))	70.38 (12.05)	80.27 (10.57)	<0.001		0.872
LOS (mean (sd))	4.94 (6.24)	4.97 (5.08)	0.232		0.005
FEMALE = 1 (%)	2021854 (53.6)	41308 (50.4)	<0.001		0.064
ZIPINC_QRTL (%)			<0.001		0.191
1	1057964 (28.0)	17425 (21.3)			
2	1008371 (26.7)	20668 (25.2)			
3	871572 (23.1)	20778 (25.3)			
4	836685 (22.2)	23107 (28.2)			
PAY1 (%)			<0.001		0.503
1	2526719 (66.9)	71452 (87.2)			
2	343437 (9.1)	2332 (2.8)			
3	689653 (18.3)	6469 (7.9)			
4	106935 (2.8)	564 (0.7)			
5	18142 (0.5)	74 (0.1)			
6	89706 (2.4)	1087 (1.3)			
PL_NCHS (%)			<0.001		0.074
1	1197251 (31.7)	23459 (28.6)			
2	976700 (25.9)	22866 (27.9)			
3	801796 (21.2)	18355 (22.4)			
4	342938 (9.1)	7556 (9.2)			
5	251841 (6.7)	5562 (6.8)			
6	204066 (5.4)	4180 (5.1)			
DISPUNIFORM (%)			<0.001		0.393
1	2354295 (62.4)	35694 (43.5)			
5	801105 (21.2)	28806 (35.1)			
6	619192 (16.4)	17478 (21.3)			
Dementia = TRUE (%)	377127 (10.0)	17935 (21.9)	<0.001		0.329
cog_imp = TRUE (%)	10596 (0.3)	851 (1.0)	<0.001		0.094
Elixhauser (mean (sd))	8.23 (10.80)	10.51 (10.96)	<0.001		0.210

***Please see Tables 3 & 4 for variable key**

Table 7. Descriptive Statistics on Index Hospitalization for Hearing loss (1) and No Hearing Loss (0) for Readmission Model (Post PSM)

	Stratified by group 0	1	p	test	SMD
n	163956	81978			
AGE (mean (SD))	80.30 (10.50)	80.27 (10.57)	0.465		0.003
LOS (mean (SD))	4.72 (4.97)	4.97 (5.08)	<0.001		0.050
FEMALE = 1 (%)	82616 (50.4)	41308 (50.4)	1.000		<0.001
ZIPINC_QRTL (%)			0.009		0.015
1	34572 (21.1)	17425 (21.3)			
2	40788 (24.9)	20668 (25.2)			
3	41324 (25.2)	20778 (25.3)			
4	47272 (28.8)	23107 (28.2)			
PAY1 (%)			<0.001		0.032
1	143528 (87.5)	71452 (87.2)			
2	4882 (3.0)	2332 (2.8)			
3	12365 (7.5)	6469 (7.9)			
4	1296 (0.8)	564 (0.7)			
5	169 (0.1)	74 (0.1)			
6	1716 (1.0)	1087 (1.3)			
PL_NCHS (%)			<0.001		0.037
1	48735 (29.7)	23459 (28.6)			
2	46453 (28.3)	22866 (27.9)			
3	35872 (21.9)	18355 (22.4)			
4	14465 (8.8)	7556 (9.2)			
5	10126 (6.2)	5562 (6.8)			
6	8305 (5.1)	4180 (5.1)			
DISPUNIFORM (%)			1.000		<0.001
1	71388 (43.5)	35694 (43.5)			
5	57612 (35.1)	28806 (35.1)			
6	34956 (21.3)	17478 (21.3)			
Dementia = 1 (%)	34564 (21.1)	17935 (21.9)	<0.001		0.019
cog_imp = 1 (%)	1578 (1.0)	851 (1.0)	0.077		0.008
Elixhauser (mean (SD))	10.19 (10.50)	10.51 (10.96)	<0.001		0.030

***Please see Tables 3 & 4 for variable key**

Table 8. Descriptive Statistics on Index Hospitalization for Hearing loss (1) and No Hearing Loss (0) for LOS Model (Post PSM)

	Stratified by group				
	0	1	p	test	SMD
n	163956	81978			
AGE (mean (SD))	80.31 (10.54)	80.27 (10.57)	0.337		0.004
LOS (mean (SD))	5.05 (5.57)	4.97 (5.08)	<0.001		0.015
FEMALE = 1 (%)	82616 (50.4)	41308 (50.4)	1.000		<0.001
ZIPINC_QRTL (%)			0.586		0.006
1	34971 (21.3)	17425 (21.3)			
2	41090 (25.1)	20668 (25.2)			
3	41329 (25.2)	20778 (25.3)			
4	46566 (28.4)	23107 (28.2)			
PAY1 (%)			<0.001		0.049
1	145069 (88.5)	71452 (87.2)			
2	4376 (2.7)	2332 (2.8)			
3	11901 (7.3)	6469 (7.9)			
4	971 (0.6)	564 (0.7)			
5	118 (0.1)	74 (0.1)			
6	1521 (0.9)	1087 (1.3)			
PL_NCHS (%)			0.010		0.017
1	47341 (28.9)	23459 (28.6)			
2	46126 (28.1)	22866 (27.9)			
3	36930 (22.5)	18355 (22.4)			
4	14805 (9.0)	7556 (9.2)			
5	10608 (6.5)	5562 (6.8)			
6	8146 (5.0)	4180 (5.1)			
DISPUNIFORM (%)			1.000		<0.001
1	71388 (43.5)	35694 (43.5)			
5	57612 (35.1)	28806 (35.1)			
6	34956 (21.3)	17478 (21.3)			
Dementia = 1 (%)	34696 (21.2)	17935 (21.9)	<0.001		0.017
cog_imp = 1 (%)	1415 (0.9)	851 (1.0)	<0.001		0.018
Elixhauser (mean (SD))	10.46 (10.65)	10.51 (10.96)	0.244		0.005

***Please see Tables 3 & 4 for variable key**

Table 9. 30-day Readmission and Length of Hospitalization for Those with Diagnosed Hearing Loss (Aims 1 and 2)

	crude OR(95%CI)	adj. OR(95%CI)	P(Wald's test)
30-day readmission	1.35 (1.32,1.38)	1.29 (1.26,1.33)	< 0.001
	crude IRR(95%CI)	adj. IRR(95%CI)	P(Wald's test)
Length of Hospitalization		0.96 (0.95, 0.96)	< 0.001

Table 10. 30-day Readmission: Exposed and Unexposed Covariates

Logistic regression predicting readmission : Exposed (1 - HL) vs Unexposed (0 – No HL)

	crude OR(95%CI)	adj. OR(95%CI)	P(Wald's test)
Elixhauser (cont. var.)	1.02 (1.02,1.02)	1.01 (1.01,1.02)	< 0.001
LOS (cont. var.)	1.03 (1.02,1.03)	1.02 (1.01,1.02)	< 0.001
DISPUNIFORM: ref.=1			
5	1.19 (1.16,1.23)	1.10 (1.06,1.13)	< 0.001
6	1.32 (1.28,1.37)	1.21 (1.17,1.25)	< 0.001
NCHRONIC (cont. var.)	1.06 (1.05,1.06)	1.02 (1.02,1.03)	< 0.001
PL_NCHS: ref.=1			
2	1.00 (0.97,1.03)	1.02 (0.99,1.05)	0.237
3	0.94 (0.91,0.97)	0.94 (0.91,0.98)	< 0.001
4	0.90 (0.86,0.95)	0.90 (0.86,0.95)	< 0.001
5	0.87 (0.82,0.92)	0.85 (0.8,0.9)	< 0.001
6	0.81 (0.76,0.86)	0.80 (0.75,0.85)	< 0.001
Dementia: 1 vs 0	0.95 (0.93,0.98)	0.91 (0.88,0.94)	< 0.001
PAY1: ref.=1			
2	1.03 (0.95,1.1)	1.02 (0.95,1.1)	0.593
3	0.8 (0.76,0.84)	0.84 (0.8,0.89)	< 0.001
4	0.78 (0.67,0.91)	0.83 (0.71,0.97)	0.018
5	0.78 (0.51,1.2)	0.85 (0.56,1.3)	0.465
6	0.85 (0.76,0.96)	0.86 (0.76,0.97)	0.017
ZIPINC_QRTL: ref.=1			
2	0.95 (0.92,0.99)	0.95 (0.91,0.98)	0.003
3	0.95 (0.92,0.99)	0.92 (0.88,0.95)	< 0.001
4	0.96 (0.93,1)	0.9 (0.86,0.93)	< 0.001
cardiac: 1 vs 0	0.89 (0.86,0.91)	0.96 (0.94,0.98)	0.001
FEMALE: 1 vs 0	0.95 (0.92,0.97)	0.96 (0.94,0.99)	0.003
AGE (cont. var.)	1.0027 (1.0015,1.0038)	0.9986 (0.9972,1.0001)	0.066
vision_imp: 1 vs 0	1.06 (0.96,1.18)	0.92 (0.83,1.02)	0.115

***Please see Tables 3 & 4 for variable key**

Table 11. 30-day Readmission: Exposed Only Covariates (Aim 3)

Logistic regression predicting readmission : Exposed covariates only

	crude OR(95%CI)	adj. OR(95%CI)	P(Wald's test)	P(LR-test)
Elixhauser (cont. var.)	1.02 (1.02,1.02)	1.02 (1.02,1.02)	< 0.001	< 0.001
LOS (cont. var.)	1.02 (1.02,1.03)	1.02 (1.01,1.02)	< 0.001	< 0.001
DISPUNIFORM: ref.=1				< 0.001
5	1.16 (1.11,1.21)	1.07 (1.02,1.13)	0.005	
6	1.25 (1.19,1.32)	1.16 (1.1,1.23)	< 0.001	
NCHRONIC (cont. var.)	1.01 (1.01,1.02)	0.99 (0.98,0.99)	< 0.001	< 0.001
FEMALE: 1 vs 0	0.93 (0.89,0.96)	0.93 (0.89,0.97)	< 0.001	< 0.001
PL_NCHS: ref.=1				< 0.001
2	1.01 (0.96,1.07)	1.04 (0.98,1.09)	0.194	
3	0.96 (0.91,1.02)	0.97 (0.92,1.02)	0.252	
4	0.91 (0.85,0.99)	0.91 (0.84,0.98)	0.018	
5	0.89 (0.81,0.97)	0.87 (0.8,0.95)	0.002	
6	0.86 (0.78,0.94)	0.84 (0.76,0.93)	< 0.001	
ZIPINC_QRTL: ref.=1				0.003
2	0.97 (0.91,1.02)	0.96 (0.91,1.02)	0.195	
3	0.93 (0.88,0.99)	0.91 (0.85,0.96)	0.001	
4	0.96 (0.91,1.02)	0.91 (0.86,0.97)	0.002	
Dementia: 1 vs 0	0.94 (0.9,0.99)	0.92 (0.88,0.97)	0.002	0.002
PAY1: ref.=1				0.011
2	1.07 (0.95,1.2)	1.07 (0.95,1.2)	0.285	
3	0.86 (0.8,0.93)	0.89 (0.82,0.96)	0.003	
4	0.87 (0.68,1.11)	0.91 (0.71,1.17)	0.457	
5	0.52 (0.23,1.21)	0.56 (0.24,1.3)	0.177	
6	0.85 (0.71,1.02)	0.87 (0.73,1.05)	0.141	

***Please see Tables 3 & 4 for variable key**

Table 12. Length of Stay: Exposed & Unexposed Combined Covariates

Incident Rate Ratios				
	Estimate	2.5 %	97.5 %	P
(Intercept)	6.47	6.30	6.65	0.001
DISPUNIFORM5	1.79	1.78	1.80	0.001
DISPUNIFORM6	1.40	1.39	1.41	0.001
Elixhauser	1.01	1.01	1.01	0.001
ORPROC	1.42	1.41	1.43	0.001
AGE	0.99	0.99	0.99	0.001
NCHRONIC	1.02	1.02	1.02	0.001
PAY12	1.22	1.20	1.25	
PAY13	0.99	0.98	1.00	
PAY14	1.06	1.02	1.10	
PAY15	1.04	0.94	1.15	
PAY16	1.04	1.01	1.07	
PL_NCHS2	0.97	0.96	0.98	
PL_NCHS3	0.95	0.94	0.96	
PL_NCHS4	0.95	0.94	0.96	
PL_NCHS5	0.93	0.92	0.95	
PL_NCHS6	0.91	0.89	0.92	
ZIPINC_QRTL2	0.96	0.95	0.97	
ZIPINC_QRTL3	0.94	0.94	0.95	
ZIPINC_QRTL4	0.95	0.95	0.96	
Cardiac	0.97	0.97	0.98	0.001
Dementia	1.04	1.03	1.04	0.001
FEMALE	0.98	0.98	0.99	0.05
visual_imp	0.97	0.95	0.99	1.00
cognit_imp	0.97	0.94	1.00	

***Please see Tables 3 & 4 for variable key**

Table 13. Length of Stay: Exposed Only Covariates

Incidence Rate Ratios				
	Estimate	2.5 %	97.5 %	P
(Intercept)	6.78	6.47	7.10	0.001
DISPUNIFORM5	1.73	1.71	1.75	0.001
DISPUNIFORM6	1.36	1.34	1.38	0.001
ELIXHAUSER	1.01	1.01	1.01	0.001
AGE	0.99	0.99	0.99	0.001
ORPROC	1.37	1.35	1.39	0.001
NCHRONIC	1.02	1.01	1.02	0.001
PAY12	1.26	1.22	1.30	0.001
PAY13	1.01	0.99	1.03	1.00
PAY14	1.09	1.03	1.16	0.01
PAY15	1.02	0.86	1.19	1.00
PAY16	1.07	1.02	1.11	0.01
Dementia	1.06	1.05	1.07	0.001
PL_NCHS2	0.98	0.97	0.99	0.01
PL_NCHS3	0.96	0.95	0.98	0.001
PL_NCHS4	0.97	0.94	0.97	0.001
PL_NCHS5	0.95	0.93	0.97	0.001
PL_NCHS6	0.93	0.91	0.96	0.001
ZIPINC_QRTL2	0.97	0.96	0.99	0.001
ZIPINC_QRTL3	0.96	0.94	0.97	0.001
ZIPINC_QRTL4	0.95	0.94	0.97	0.001
Cardiac	0.98	0.97	0.99	0.001
FEMALE	0.99	0.98	1.00	0.05
visual_imp	0.98	0.95	1.01	1.00

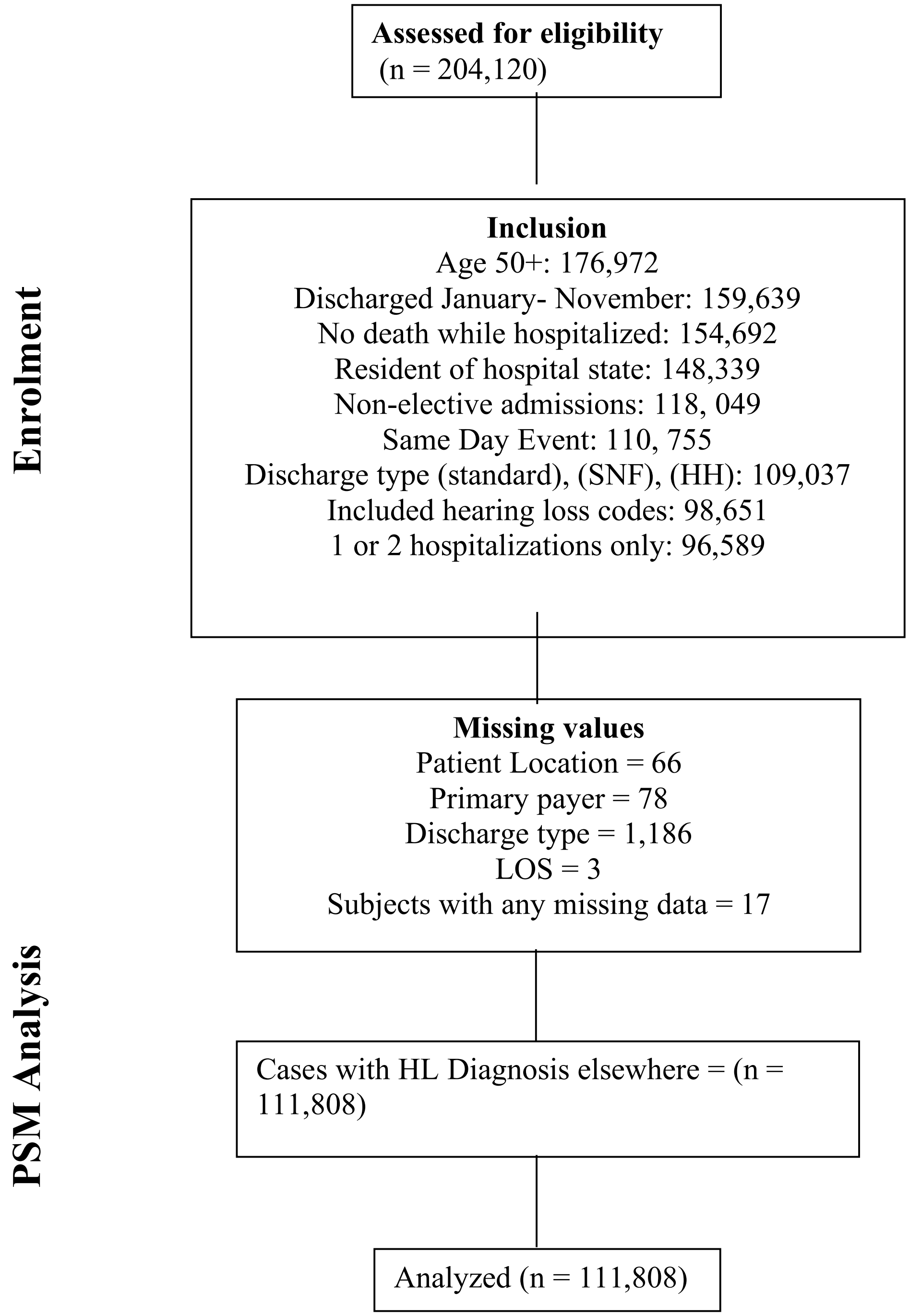
***Please see Tables 3 & 4 for variable key**

Table 14. Frequencies of Most Common Primary 30 Day Readmission Diagnoses by Group

Diagnosis Code	Diagnosis Name	No HL (Unexposed)	No HL (Unexposed) (%)	Diagnosis Code	Diagnosis Name	HL (Exposed)	HL (Exposed) (%)
038.9	Septicemia	21949	5.54	486	Pneumonia	521	4.46
486	Pneumonia	13884	3.51	584.9	Acute Kidney Failure	371	3.17
584.9	Acute Kidney Failure	11919	3.01	599.0	UTI	367	3.14
491.21	COPD w/ Acute exacerbation	11440	2.89	427.31	A Fib	322	2.75
427.31	A Fib	9090	2.3	038.9	Septicemia	281	2.4
410.71	STEMI	9067	2.29	410.71	STEMI	268	2.29
599.0	UTI	8853	2.24	491.21	COPD w/ Acute exacerbation	244	2.09
428.23	Systolic CHF	6846	1.73	428.33	Diastolic CHF	241	2.06
434.91	Cerebral Infarction	6255	1.58	434.91	Cerebral Infarction	234	2
428.33	Diastolic CHF	5894	1.49	820.21	Closed Fracture; Femur neck	203	1.74
414.01	Coronary Atherosclerosis	4729	1.19	428.23	Systolic CHF	188	1.61
682.6	Cellulitis of leg	4667	1.18	507.0	Food/vomit Pneumonitis	164	1.4
428.0	Unspecified CHF	4143	1.05	682.6	Cellulitis of leg	126	1.08
518.81	Acute Respiratory Failure	3995	1.01	428.0	Unspecified CHF	118	1.01

577.0	Acute Pancreatitis	3508	0.89	820.8	Closed Fracture; Femur; unspecified	108	0.92
518.84	Respiratory Failure	3487	0.88	414.01	Coronary Atherosclerosis	106	0.91
562.11	Diverticulosis of colon	3445	0.87	276.1	Hyposmolality and/or hyponatremia	98	0.84
578/9	GI Hemorrhage	3177	0.8	780.2	Syncope & Collapse	93	0.8
507.0	Food/vomit Pneumonitis	3109	0.79	435.9	Cerebral Ischemia; Unspecified	92	0.79
560.9	Intestinal Obstruction; Unspecified	3077	0.78	518.81	Acute Respiratory Failure	92	0.79

Figure 1. CONSORT DIAGRAM: OBSERVATIONAL STUDY – EXPOSED COHORT



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CHAPTER 5: DISCUSSION

Few studies have investigated healthcare experiences and outcomes in older adults with hearing loss. This dissertation is comprised of three separate papers and two projects which focus on healthcare experiences and outcomes in older adults with hearing loss. Healthcare experiences included investigations of feasibility and acceptability of using amplified hearing accommodations for patients with hearing loss in acute care settings. Patient satisfaction as well as nursing satisfaction and nursing perceived productivity was measured. For healthcare outcomes, studies assessing associations among hearing loss, hospitalization, readmission and mortality were synthesized to better understand the relationships. The focus of the review also included potential confounders, hearing screening, and hearing aid use impact on these relationships. Further investigation on healthcare outcomes for patients with hearing loss was conducted using the National Readmission Database to assess the association between hearing loss and community hospital readmission and length of stay in older adults. Common diagnoses and covariates associated to these outcomes were also investigated within these models.

Paper 1, Chapter 2: Amplified Hearing Device Use in Acute Care Settings for Patients with Hearing Loss: A Feasibility Study

This study demonstrates that hearing accommodations for patients with hearing loss in acute care settings can be safe as well as easily utilized and accepted by patients and hospital staff. Previous research has demonstrated support that hearing accommodation use can result in decreased risk of negative health outcomes such as disuse of appropriate healthcare services and mortality. Future research should prioritize investigating if hearing accommodation use in acute care settings could decrease adverse health outcomes such as longer length of hospitalization, readmission, comorbidity, and mortality risk.

Patient Satisfaction

24 out of 25 patients were satisfied with utilizing hearing accommodations during their hospitalization and expressed interest in using the device in future hospitalizations. Patient satisfaction with the hearing accommodation indicates a potential incentive for hospitals to provide free and accessible accommodations to improve patient care and patient perception of care. One patient reported dissatisfaction with using the hearing device and this same patient had a HHIE-S score of 40, and wore hearing aids regularly. This suggests that assistive hearing devices may not work as well for those with severe hearing loss, or who are accustomed to personal hearing aids.

Another novel finding is of the 25 patients, 16 wore hearing aids with 10 of the 16 wearing them regularly. None of the included patients in the study brought hearing aids into the hospital upon admission as patients were excluded if they brought hearing aids to the hospital. The rationale for this is that hearing aids are often tailored to the patient and as a result often work better than the provided amplified hearing device. This study indicates that though patients may own hearing aids, they often may not bring them to the hospital due to emergent admissions, or for fear of them being lost, stolen, or broken. Future research could investigate how many patients diagnosed with hearing loss bring their hearing accommodations to hospitals if they own any, and the reasons for their choice.

Nursing Satisfaction and Productivity

All 15 nurses were satisfied with using the amplified hearing device with their hard of hearing patients. All 15 nurses also felt that using accommodations decreased their time spent with the patients. This is a novel finding as it suggests that accommodation use for patients with hearing loss may not only benefit the patients, but also the hospital staff that work with them.

Paper 2, Chapter 3: Associations among Hearing loss, Hospitalization, Readmission, and Mortality in Older Adults: A Systematic Review

Hearing loss was found to have an increased risk or odds of negative health outcomes pertaining to all outcomes under study as three mortality, three hospitalization and one readmission study found significant associations after all adjustments. However, whether hearing loss has an independent effect is not well known as several studies indicate other potential confounders and mediators on the relationships. Variables that had potential confounding and mediating effects consisted of age, sex, cognitive impairment, walking ability/mobility, self-rated health, and cardiac factors. Future studies should prioritize accurate measurement and adjustments for commonly known confounders in the relationships whenever possible (e.g. cognitive impairment, multiple impairments).

Hearing Screening

Studies varied in hearing screening method and hearing loss definitions which made comparisons difficult. However, this review does give valuable insight on the relationships under study. Studies that indicated significant associations after all adjustments typically used objective hearing screenings such as audiometric testing whereas studies that used subjective testing measures such as self-reported measures typically resulted in no significant associations after all adjustments. Subjectively screened studies were also more likely to result in less significant associations before adjustments or after minimal adjustments. This is not surprising as hearing loss is often under or misdiagnosed which strongly suggests potential predictor contamination in the control/hearing group which could bias results to the null hypothesis.

Even when studies used the gold standard audiometric testing, they often varied in their definition for hearing loss making comparisons difficult. However, several studies which stratified by hearing loss severity found that moderate to severe hearing loss had stronger associations to these negative outcomes compared to mild and no hearing loss. Adhering to a world recognized hearing loss definition such as World Health Organization would improve the ability to compare studies and synthesize findings.

Hearing Aid Use

One of 4 hospitalization and five of 15 mortality studies accounted for hearing aid use in their analyses. The one hospitalization study found that though hearing aid use had no significant association with incident or rate of annual hospitalization, the utilization of hearing aids was found to shorten the length of hospitalization. Furthermore, 2 of the 5 mortality studies found that hearing aid use made a significant difference in mortality risk. Though these studies provide important insight on this phenomenon, they accounted for minimal to no socioeconomic factors (income, education, occupation). This is important to note as hearing aids are expensive and often cost prohibitive for older adults as they are often not covered by insurance.

Paper 3, Chapter 4: Hearing Loss and the Association with Community Hospital Readmissions in Older Adults: A Secondary Analysis using the National Readmission Database

Readmission & Length of Hospitalization

Hearing loss diagnoses was significantly associated to higher odds of 30-day readmission and lower incidence of length of hospitalizations compared to a 2:1 matched cohort of those with no hearing loss diagnosis. Even after block and propensity score matching for known confounders such as patient discharge location, sex, age, income, insurance, patient location, Elixhauser comorbidity index scores and various comorbidities, patients with diagnosed hearing loss still had significantly higher odds of readmission and lower incidence for length of hospitalization. This is the first known study of its kind to account for patient discharge location in the association between hearing loss and readmission. This is novel as patient discharge location is a commonly known confounder in several associations investigating negative healthcare outcomes including hospitalizations, readmissions and mortality. This suggests that patients with hearing loss may have higher hospital readmission and slightly shorter length of hospital stay independent of discharge type.

Covariates

This is the first known study of its kind to examine various covariates in association between patients with diagnosed hearing loss and 30-day readmission and length of hospitalization. Common covariates associated to higher odds of 30-day readmission in the exposed were male sex, no dementia diagnoses, higher Elixhauser comorbidity index scores, longer hospitalizations, discharge to skilled nursing facilities or with home health, living in more populated areas, lower income, and covered by Medicare insurance. Common covariates associated to longer length of hospitalizations in the exposed were male sex, no cardiac diagnoses (of which we accounted for), OR procedures in index hospitalization, higher number of chronic conditions, higher Elixhauser comorbidity index scores, dementia diagnoses, living in more populated areas, lower income, and covered by Medicaid, self-pay and categorized as other.

Primary Readmission Diagnoses

This is the first known study of its kind to investigate primary 30-day readmission diagnoses for patients with diagnosed hearing loss. One novel finding of this study was that patients with diagnosed hearing loss had higher frequencies in readmissions for diagnoses commonly associated to falls (fracture of femur and syncope) compared to patients without a hearing loss diagnoses. Hearing loss and falls has been well studied and previous research indicates hearing loss is associated to an increase risk/odds of falling.

Significance to Nursing

Nurses are considered to be the largest group of healthcare workers within the healthcare delivery model as they are on the front lines in patient care and often have the most contact with patients. Nurses teach patients about their disease processes, medication regimens, and healthcare skills needed to improve patient safety by ensuring it is not compromised by the patient's inability to manage their own healthcare needs. Patients often turn to nurses for clarification regarding their own healthcare information and it is part of the nurses' responsibility to ensure that patients understand appropriately. Teaching and clarification are not only reserved for discharge teaching but occurs throughout hospitalizations and follow up appointments. It is important for patients to have access to their health information repetitively as repetition often assists with processing, retention, and understanding which could subsequently lead to better patient adherence and ultimately lower negative health outcomes (Grice et al., 2014; Parle, Singh N Fau - Vasudevan, & Vasudevan, 2006). Hearing accommodations has also been linked to improved health outcomes in previous research. In addition to repetition of instructions by nurses, hearing accommodations in healthcare settings could improve patients' access to their health information subsequently potentially improving health outcomes.

Nurses play an important role in ensuring patients access to their health information through communications between patients and healthcare providers. Armed with the knowledge that hearing loss is often under identified and associated with negative preventable health outcomes as well as hearing accommodations being a possible quality improvement intervention, nurses are at a unique position to enforce policies and procedures to improve healthcare delivery and quality of life for these patients. This unique position also allows nurses to assist with identifying when patients may have a hearing loss and alerting them to the appropriate providers to request appropriate referrals or acquire accommodations. Moreover, nursing has been viewed as one discipline that could guide the application of new technology into clinical practice (Huston, 2013), and help guide policy decisions designed to improve the healthcare experience of persons aging with disabilities. Nurses can play a vital role in future research studies and policy implementations as they can provide valuable insight on the feasibility of utilizing certain hearing screenings, hearing accommodations, and appropriate referrals in various healthcare settings. Because of nurses vital role in the quality of healthcare for patients, the inclusion of nurses in future studies investigating implementation of screenings and interventions in various healthcare settings is paramount to ensure acceptability, efficacy, and sustainability.

Implications for Research

This dissertation, though informative, also identifies several gaps in knowledge in both research and practical settings. Future research should prioritize further investigations in hospitalization, readmission and mortality outcomes using longitudinal prospective design. Further investigations are needed to determine if early identification and effective management of age-related hearing loss, whether through screening, hearing aids, assistive listening devices or other methods, could decrease adverse health outcomes such as hospitalizations, readmission and mortality. It is important to investigate these relationships prospectively with priority on potential mediating factors such as patient low activation, low health literacy, lack of accommodations, unintentional nonadherence and lack of identification as it could assist with determining where the largest impact can be made through practice and policy for these patients.

More research is also needed to assess different types of hearing screenings in various healthcare settings. For example, healthcare settings vary drastically therefore studies should consider that one type of hearing screening method may not be feasible all across different healthcare settings (Inpatient: ER, ICU, Med-Surg or Outpatient: primary care, initial specialty visits). The need to identify what screening methods are optimal in various healthcare settings is important as this may increase the likelihood of hospital/healthcare staff of following through with conducting these hearing screenings.

Though using healthcare databases poses some benefits to answering research questions, future research should investigate how hearing loss is coded, when it is coded, how often it is coded, and by whom it is coded. Hearing loss screening type as well as hearing loss severity should also be strongly considered. This is important as with hearing loss being the primary predictor of interest, any variation in identification and diagnoses type, time and accuracy can skew results. Future research should also prioritize studies investigating the number of patients diagnosed with hearing loss whom bring their hearing aids to the hospital, and the reason for their choice.

It is also recommended that future studies screen for hearing loss using audiometry, adhere to established audiometric definitions of hearing loss (i.e., World Health Organization classification of hearing loss), accurately measure and control for common confounders, abstain from aggregating hearing loss severity, and stratify for age and sex to optimize results.

Implications for Policy

This dissertation provides several revelations regarding possible policy implications.

Hearing loss is often unidentified or misdiagnosed due to several reasons such as patient knowledge of hearing status, hospital staff (i.e. physicians, nurses) knowledge of implications of untreated hearing loss, and hospital staff time constraints and lack reimbursement. Policies focusing on hearing screening such as incorporating easy to use hearing screening techniques in the physical exam should be made a priority for adults aged 50 and older during healthcare visits including primary care and inpatient visits. Future policies need to consider the most optimal hearing screening tool for healthcare settings as hearing screenings should be applied at least every 3 years for all adults aged 50 and older as recommended by ASHA. For example, though audiometric testing is considered the gold standard for screening hearing loss, it is not feasible to apply this screening method in all healthcare settings. However, other types of hearing screenings such as scales or finger rub could suffice as a measure (Strawbridge & Wallhagen, 2017). One recommendation for initial hearing screening for all patients older than 50 is to use the easy to apply Hearing Handicap Inventory for the Elderly Screening version which is a 10 item questionnaire (Ventry & Weinstein, 1983). This could be conducted during their annual physical or during an inpatient visit if they have no record of being tested previously. If patients have a score of 10 or higher then these patients could be tested further with a finger rub test or handheld audiometric testing tool. Patients can then be seen by an audiologist who can provide appropriate short term hearing accommodations for inpatient stays such as assistive listening devices that fit the patient. Prior to patient discharge physicians can write referrals to audiologists for these patients. For outpatients, physicians can screen for hearing status using the HHIE-S, finger rub test or hand held audiometry then write audiology referrals for these patients. Physicians should prioritize the proximity of the audiological referrals (audiologists) to the patients homes over ensuring these referrals stay within the physicians network. It is important for healthcare providers to ensure that patient perceived barriers to making follow up appointments are appropriately addressed such as making their follow up appointments closer in proximity to patient residence as this will increase the likelihood of patients attending these appointments (Crutchfield & Kistler, 2017). Prior to choosing an appropriate hearing screening method for healthcare settings, more research needs to be conducted investigating the screening techniques that are most optimal. For example, healthcare settings vary drastically therefore studies should consider that one type of hearing screening method may not be feasible all across different healthcare settings (Inpatient: ER, ICU, Med Surg or Outpatient: primary care, initial specialty visits) hence the need for further research (Zitelli & Palmer, 2017).

Hearing accommodation use has been linked to improved health outcomes for patients with hearing loss in studies that investigated this phenomenon. Though more research in this area is needed, considerations of future policy implementation focusing on providing hearing accommodations for patients with hearing loss within and outside of healthcare settings on either on an organizational, state, or federal level should be made a priority. As previously discussed in this dissertation, hearing aids are often cost prohibitive for older adults as insurance rarely covers them (Donahue, Dubno, & Beck, 2010). Even less costly alternatives such as assistive listening devices may not be covered by health insurance (Mamo, Reed, Nieman, Oh, & Lin, 2016), thus potentially resulting in older adults opting out of making the much needed purchase. Despite the evidence of hearing accommodations potentially improving health outcomes in these patients there have been few attempts to offset the consequences of hearing loss in older adults on a policy level. For example, there was a recent policy change for over the counter hearing aids with the FDA reauthorization act (FDARA) which was signed to law on August 18, 2017 allowing sale over the counter hearing aids ("FDA Reauthorization Act of 2017 (FDARA)," 2018). However, as of July 2019 there are no over the counter hearing aid devices that meet the FDA criteria that can be sold. Therefore, older adults with hearing loss are still required to obtain hearing aids the traditional way (audiology appointment, prescription) (FDA, 2018). Hearing aids are often not covered by insurance for older adults, however, unsurprisingly, insurance coverage for hearing aids mainly cover children. Eighteen states in the US require insurance to cover hearing aids for children (Colorado, Delaware, Georgia, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Missouri, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Tennessee, Texas and Wisconsin) (ASHA, 2019). This is compared to 5 states requiring insurance coverage for all ages (Arkansas, Connecticut, Illinois, New Hampshire, and Rhode Island). Requirements varied by state for the ages covered, amount of coverage, benefit period, and provider qualifications (ASHA, 2019). Hearing aids are costly as hearing aids can range in price from $1,500 to $3,500 from low to high end, respectively. Furthermore, since age related hearing loss often occurs bilaterally and symmetrically, approximately 80% of older adults with hearing loss need 2 of them (Hlayisi & Ramma, 2018). The need for more hearing aid coverage in older adults aged 50 in older in all states is evident, however to convince insurance to provide adequate hearing aid coverage, more research needs to be conducted to assess the impact of hearing aids on various health outcomes in this population.

One key revelation of this dissertation with significant policy implications is the finding of diagnoses closely related to falls being a common primary 30-day readmission diagnoses in those with hearing loss. Sensory impairments such as hearing loss and vision loss have both been associated with higher risk of falls in several studies (Jiam, Li, & Agrawal, 2016). Twelve states have passed legislations that regard to falls in older adults (California, Connecticut, Florida, Hawaii, Maine, Massachusetts, Minnesota, New Mexico, New Jersey, Oregon, Texas and

Washington) ("Elderly Falls Prevention Legislation and Statues," 2019). There are 10 states with 15 total pending legislation bills pertaining to fall risk in older adults. These states include California, Connecticut, Washington D.C, Florida, Massachusetts, Minnesota, New Jersey, New Mexico, New York, and Virginia ("Injury Prevention Legislation Database," 2019). Though these legislative efforts are beneficial, they may not be enough to adequately address fall risk in older adults in the country. With the rapid growth in population size of older adults, bills in all states need to be passed regarding fall risk safety.

Fall risk assessments are often used in healthcare settings to assess patients' risk of falls. This is done so healthcare providers can accommodate the patients accordingly to reduce falls such as using bed alarms or placing fall risk signage in rooms or on patients' wrist bands. These assessments can also be used in primary care settings and can be combined with other procedures such as aging in place to ensure patient safety and independence at home. While fall risk assessments often do include assessments of pertinent information such as patient mobility, fall history, cognition, and medications, they often do not incorporate sensory impairments such as vision and hearing loss. Often, patients with a fall history do not understand their own personal risk which indicates a lack of effective communication between patients and providers (Hendrich, 2006). There are several common fall risk assessment tools such as the Morse Fall Scale, Stratify Scale, Hendrich II Fall Risk Model, Johns Hopkins Fall Risk Assessment Tool, and STEADI (Cumbler, Simpson, Rosenthal, & Likosky, 2013; Price, 2015). It is important to note that none of these fall risk assessments include hearing loss (Cumbler et al., 2013). Due to the significant association found between hearing loss and falls in previous research and our findings of diagnoses closely associated to falls in the hearing loss population, it is highly recommended that fall risk assessments incorporate sensory impairments such as vision loss and hearing loss. It is also highly recommended that future research investigate the impact of hearing accommodation use on falls as this phenomenon is unknown. The incorporation of hearing loss in fall risk assessments could result in improved identification of patients at risk of falls subsequently resulting in more appropriate and specialized care. This could also assist with lowering odds of 30-day readmission in patients with hearing loss.

Prioritizing the implementation of suggested future research and policies could assist with avoiding inappropriate healthcare utilization as well as negative healthcare experiences and health outcomes.

Key Practical Suggestions to Reduce Readmission in Patients with Hearing Loss

- **Ask adults over 50 about hearing status if no evidence of screening in past 3 years.**
    - If patients identified initially via self-report then
        - Consider taking advantage of hearing accommodations if they are freely provided in that healthcare setting during appointments/ inpatient stays
        - Consider prioritizing audiology referrals regardless if they are inpatient/outpatient – make follow up audiology appointments close in proximity to patients' residence if outpatient
        - Talk with patients about the implications of untreated hearing loss
- **Implement strategies to ensure patients with hearing loss understand their health information.**
    - Prioritize teach back methods, especially with new health information, to ensure patient comprehension
    - Prioritize providing written information regarding disease processes, medication regimens and skills needed for care.

    - Consider highlighting and verbally repeating the most important parts of all written documents
    - Optimize verbal communication by
        - ensuring the environment is well lit
        - facing patients directly during all communications – do not turn your back or wear traditional surgical masks while talking to patients
        - decreasing background noise by shutting doors or turning off TVs/radios
        - speaking at a normal level with consistent cadence and prioritize enunciation of words to assist with clarity
        - rephrasing instead of repeating statements if patients don't initially understand
        - utilizing FDA approved see through surgical masks when necessary
- **Include sensory deficits in risk management assessments.**
    - Include sensory deficits, especially hearing loss, in fall risk whether it is already included in the chosen fall risk assessment or supplementary.
    - Incorporate educational programs regarding aging with an emphasis on hearing screenings, implications of untreated hearing loss and available accommodations. These should be provided annually for various healthcare settings for all employees – prioritize additions of new research in this area and provide sufficient information from difficult to obtain articles
        - Also incorporate for various allied health programs such as medicine, nursing, dentistry, therapy etc.

Conclusion

This dissertation suggests further research hearing loss associations among negative health outcomes as well as healthcare experiences is needed in a prospective design. In line with previous research, this dissertation also suggests that prioritizing and investing in research and accommodations for patients with hearing loss may potentially improve health outcomes, as well as healthcare experiences for hard of hearing patients and the hospital staff who work with them.

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